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Author's Foreword

For several years the author has had in mind, and has been gradually working toward, the preparation of such a work as this, from various points of view. Every applied science demands an encyclopedia and dictionary which crystallizes its subject-matter and standardizes its nomenclature. Ocular refraction, which in the last twenty-five years has developed into the fullness and dignity of an independent applied science, had no such representation. What was still more important, as ocular refraction became more and more voluminous and many-sided, it seemed very desirable that its various phases should all be assembled in co-ordinated form, between the covers of a single book, where the whole subject could be conveniently and comprehensively studied. A complete, unabridged encyclopedia and dictionary fulfills both of these desiderata.

It takes two sets of forces, however, to produce a worth-while book, viz., authorship and publication; and this dream of the author's would have remained a barren, half-realized dream, of no practical service to the profession, if it had not met its necessary complement. It fortunately happened that another man cherished the same vision, and possessed the capacity, the experience, the energy and the organization to give it tangible, concrete form. That man was the president of the Professional Press, through whose efficient instrumentality the undertaking now emerges as an accomplished fact.

In the preparation of the book both author and publisher have held steadily before them two paramount aims: (1) That it should completely cover the ground, so that, as the publisher frequently expressed it in his cogent way, "Nobody, looking in it for whatever information, should have to close the covers and say 'It isn't there'." (2) That it should be written and arranged in such a way as to be of maximum usefulness to the practising refractionist with a minimum of difficulty or trouble. Every step of the work has been taken with these two purposes in view. How successfully they have been achieved, the reader must judge.

Another consideration was kept in mind, which might or might not have contributed to the main purposes as set forth

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above, according to the care and skill with which it was handled, namely, that the text should be as concise as possible without impairing its effectiveness, avoiding unnecessary repetition and prolixity of language. In the carrying out of this consideration, the various phases of the subject have been thoroughly discussed, in every instance, under the major heading to which they respectively belong; minor headings are briefly defined, and a cross-reference given in each case, to the major heading under which a full account may be found.

It has been impossible, of course, to prepare a work of this character without having frequent recourse to consultation and comparison of many text-books and works of reference, too numerous to mention. Where any of these have been directly cited, proper credit is given in the text. Special obligation must here be expressed to Dr. Chas. Sheard, Physiologic Opticist to the American Optical Company, and Editor of the American Journal of Physiologic Optics, for the entire article on "Ophthalmometry"; to Robert D. Pettet for the section on "Frame Fitting"; and to the artists and printers who have so efficiently cooperated to make a finished book.

T. G. A.

CHICAGO, ILL.
AUGUST 18, 1921.

OCULO-REFRACTIVE CYCLOPEDIA AND DICTIONARY

Abducens. A descriptive name given to the sixth pair of cranial nerves, because their function is to enervate the external rectus muscles and turn the eyes outward. The term is also sometimes applied, but wrongly, to the external rectus muscle itself. For detailed account of the abducens, see **Nerves.**

Abduction. The turning of the eyes outward beyond the median line by the external rectus muscles. The effect is known as negative convergence. It can be performed by the external recti alone, and whether the obliques ordinarily aid or not is not known. It is regarded as an involuntary function; but under the stimulus of prisms (base in), and the desire for a single image, it can be forced.

Power of abduction is expressed in terms of prism dioptres, the deviation of the visual axis from the median line being considered similarly to the deviation of a ray of light by a prism. It may be measured by finding the strongest prism, base in, with which the eyes can maintain single vision. Normally, this amounts to 8 or 10 prism dioptres.

The word is also applied to the exercises of the external rectus muscles by means of graded or rotary prisms, base in. The value of such exercises is questionable. (See **Convergence.**)

Abductor. A general term applied to any muscle which turns the part to which it is attached outward from the median line. In opthalmology, the external rectus muscle of the eye.

Aberration. In optics this term is specifically applied to the failure of refracted rays of light to find a common focus. There are two forms of aberration recognized, namely, chromatic and monochromatic or spherical.

(1) Chromatic aberration is the non-uniform focussing of the different color waves in a pencil of light, due to the dif-

ferent refrangibility of these waves, the short violet waves being refracted most, the long red waves least, and intermediate waves in proportional degrees. Chromatic aberration is greatly accentuated in prism refraction, and this is responsible for the separation of the color waves in the spectroscope. (See **Spectrum.**) It is also made the basis for testing the refraction of the human eye. (See **Chromatic Test.**)

(2) Monochromatic, or spherical, aberration is the failure of a spherical refracting body properly and uniformly to focus rays of light which fall upon its surface at certain angles. The strict truth of the matter is that all refracted rays are aberrant. The theory of object and image points (Gaussian theory) holds good only so long as the angles made with the principal axis are infinitesimally small, with infinitesimal objects, images, and thicknesses. All images produced by uncorrected systems are ill-defined and blurred, if the apertures, or fields of view, exceed certain limits. The wider the apertures, i. e., the larger the angles made with the axis, the greater the aberration. Hence spherical aberration is greatest at the periphery of the spherical surface.

There are four principal phases of monochromatic aberration:

(1) Aberration of axial points.

(2) Aberration of elements, i. e., smallest objects at right angles to the axis.

(3) Aberration of lateral object-points.

(4) Distortion of the image.

Astigmatism is an example of the last two phases of aberration.

The human eye experiences both these forms of aberration; however, so far as spherical aberration is concerned, the iris cuts off these aberrant waves and prevents them from entering; and chromatic aberration is normally so slight as to be negligible. The same holds good for the aberration of lenses used in front of the eyes. In instruments of great precision, as microscopes, telescopes, etc., aberration is largely overcome by a special combination of substances in the construction of the lenses. (See **Achromatism.**)

Abscissa. In optics, a dimension used to designate the position of the point where a ray of light crosses the principal axis with respect to the vertex of the reflecting or refracting surface as an origin. For reflection $v_1 = -v$, where v_1 is the distance in front, and v the distance behind the plane mirror. For refraction, where u is the distance in front of the lens, v the distance behind, n the index of the first medium and n_1 the index of the second medium, then

$$v = \frac{n_1}{n} \times u$$

Absolute. The word has various technical meanings in optics, all of which, however, have the common idea of an extreme limit.

Absolute hyperopia is a degree of hyperopia that cannot be compensated for at infinity by means of accommodation.

Absolute index of refraction is the power of a medium to refract waves which enter it from a vacuum.

Absorption. As applied to optics this term refers to light waves which enter a body or substance and do not emerge from it, being stopped or transformed into some other form of energy during their passage. Such waves are said to be absorbed.

All substances absorb light to a more or less degree, and it is the relative degree of absorption for different radiations which gives to various substances their distinctive qualities of visibility and color. A body which should absorb all light would be a "perfectly black body," but no such body actually exists. Most bodies show a selective power, readily absorbing certain wave-lengths and others not so readily.

The law which governs absorption is simple. Whatever percentage of the original intensity of the light is absorbed in the first unit of penetration, the same percentage is absorbed in the second unit, and so on. Thus, the original intensity of light decreases by a continuous arithmetical progression, according to the power of absorption of the body for this particular radiation. If I stands for the intensity at any given depth of penetration, Io for the original intensity, j for

the amount of absorption in the unit of penetration, and t for the unit of penetration, then

$$I = Io\ (1 - j)^t$$

The question of absorption by ophthalmic lenses is an important one. In the main, lenses should be as transparent as possible, i. e., they should absorb as little as possible of the waves which have to do with visibility. It is often desirable, however, to keep certain waves from reaching the eye, e. g., the actinic and violet waves, and special forms of lens are made whose composition absorbs these undesirable waves. Amber lenses are of this character. Smoked lenses exercise a rather uniform absorption for all light waves, and thus serve to cut down the total amount of light entering the eye.

Accommodation.

MECHANISM OF ACCOMMODATION.

The aspects of accommodation as a physiologic function, including a description of the nervous paths by which it is mediated, will be found in the section on **Physiology of Vision.** This discussion of the mechanism of accommodation will be restricted to the purely mechanical side of the subject.

We know that accommodation is ultimately attained by increasing the convexity of the crystalline lens, principally, if not altogether, of the anterior surface of the lens, and that this is dependent upon the elasticity of the lens and its capsule. That this change in the shape of the lens actually takes place is readily demonstrable by a very simple experiment.

If a lighted candle be held a foot or so from the eye of a person who is gazing into the distance, a little to one side, so as to form an angle of about 30 degrees with the median line, and the observer's eye be placed at the same distances on the other side of the median line, three images of the candle will be seen reflected from the subject's eye: (1) an upright image formed by the cornea, (2) a second, larger upright image, formed by the anterior surface of the lens, and (3) a smaller, inverted image formed by the posterior surface of the lens.

If, now, the subject be directed to look at a point close to his eyes, images 1 and 3 remain unchanged in shape, size and

position, but image 2, which is formed by the anterior surface of the lens, becomes smaller, more distinct, and approaches image 1, proving that this surface has become more convex and approached the cornea.

The precise mechanism by which this change in the lens is brought about is not so easy of demonstration. Two commonly-held theories divide the field. Both of these theories agree that the active factor in the process is the contraction of Mueller's muscle, the sphinctre muscle of the ciliary; but they disagree as to the mechanical effect of its contraction.

Helmholz, who was the first to investigate the phenomenon of accommodation, taught that the contraction of the ciliary muscle, by drawing forward the chorioid, relaxes the tension of the zonula, and permits the lens, in virtue of its elasticity, passively to assume a form more nearly approximating the spherical. At the same time there is necessarily produced a corresponding decrease in the equatorial diameter of the lens; its equator accordingly recedes inward toward the axis of the eye, and is thus kept from coming in contact with the ciliary processes as they advance.

According to Tscherning, the contraction of the ciliary muscle tightens instead of relaxing the zonula, altering the lens surface from a spherical to a hyperboloid form. According to this theory the bulging of the lens into more convex shape is produced by an active compression by Mueller's ring, and not by a passive exercise of the elasticity of the lens.

Both theories have their merits and demerits. In favor of Helmholz's theory is the significant fact that whenever the lens is divided from the fibres of the zonula, (as in extraction), it rapidly assumes a spherical form. In support of Tscherning's doctrine is the equally significant fact (which, indeed, led Tscherning to his belief), that in accommodation, while the central part of the anterior surface of the lens is bulged, the peripheral portion is flattened. Helmholz's theory is the more generally accepted, although it does not satisfactorily account for all the phenomena of accommodation.

The actual physical change effected in the crystalline lens by accommodative muscular effort in a young person is expressed in the following comparison of thickness and curva-

tures in the static condition and at the height of accommodation:

	Far Point.	Near Point.
Thickness	3.7 mm.	4 mm.
Anterior radius	10 mm.	6 mm.
Posterior radius	6 mm.	5 mm.

This comparison shows how much more markedly the anterior surface is affected than the posterior.

The sphinctre iridis and, if binocular vision is present, the internal rectus muscles, contract in association with the ciliary muscle. The act of accommodation, therefore, is regularly accompanied by a contraction of the pupil and by the act of convergence.

RELATIVE ACCOMMODATION.

Not only is the act of accommodation regularly accompanied by the act of convergence, but a certain quantitative ratio is normal between the two. Thus, for 1 meter angle of convergence (i. e., convergence to 1 meter distance) the eye normally exerts 1 D. of accommodation. However, it is always possible, by means of minus lenses, to force a certain amount of additional accommodation at this point; and by means of convex lenses to suppress a certain amount. These forced and suppressed quantities are known, respectively, as positive and negative relative accommodation. The difference between the two is said to be the relative accommodation of the eye.

It is due to this latitude of relative accommodation that every ametrope is not doomed to strabismus and amblyopia. For if the ratio between accommodation and convergence were an absolutely fixed quantity, every ametrope would have to choose between two alternatives: either to see distinctly but double, because of defective convergence, or else to see singly but indistinctly, because of the defective accommodation.

This relative amplitude of accommodation, however, has its limits. A hyperope of a certain degree may succeed, with an effort, in achieving the excess accommodation demanded by his error of refraction while he maintains emmetropic convergence. But if, for any reason,—such as nervous disturbance, headache, etc., or inequality of visual acuity in the two retinae—it should be much easier to disregard one of the

images than to maintain relative accommodation, then he is likely to lapse into squint. Or, if the amount of refractive error be greater than can be compensated by relative accommodation, then the patient usually chooses the alternative last mentioned above—to see singly but indistinctly; or, rather, he gives up trying to see closely at all, just as the myope does.

It has also been established by repeated experiment that the amount of convergence exerted in association with accommodation for a given point is not all of it a co-ordinate of the accommodation. It would appear, from these experiments, that in the majority of cases only two-thirds of it is co-ordinate with the accommodation, the other one-third being exercised separately and distinctly. This will be fully discussed in treating of convergence.

The exploration of a patient's relative convergence is of importance, because it represents what is known in engineering as the "flexibility" of the function. It measures, in fact, the power of the accommodation center to function independently of its association with convergence. It constitutes, therefore, one of the chief factors in reaching a conclusion as to the patient's need of assistance.

ACCOMMODATIVE RESERVE.

It is an established fact that no person can exert his total amplitude of accommodation for any great length of time, or for ordinary purposes. It is usually held that he must keep at least one-third of it in reserve. This estimate, however, as we shall see, is subject to considerable variation in individual cases.

MATHEMATICS OF ACCOMMODATION.

The optical mathematics of accommodation is very simple, although it may give rise to many complicated problems. The normal eye in its static condition is adapted to infinity, i. e., to focus neutral light waves at its retinal plane. In order to focus finite, or positive, waves at the same focal plane, it must necessarily add to its dioptrism exactly enough power to neutralize the positive wave and render it as though it came from infinity. In other words, it must add to itself the exact dioptric equivalent of the positive curvature of the wave at

the point where it strikes the cornea. (It is to be observed, in passing, that the actual physical curvature to be added to the crystalline lens must be greater than the metric curve of the light wave it is to neutralize, because only a portion of the lens-curve is available for dioptric effect.)

Again, the distance of the light wave's point of origin from the eye is the radius of its curvature when it strikes the eye; and the same distance is the radius, or focal length, of the dioptric power which the eye, by its accommodation, adds to itself for the purpose of neutralizing the wave. Whence we deduce the simple rule that, in the normal eye, accommodation is the reciprocal of the distance for which it is exercised. Either quantity divided into unity will give us the other. Thus, for an object at 50 cm. the eye uses 2 D. of accommodation; if it exercises 4 D. of accommodation, it is adapted for an object 25 cm. distant.

In the case of a hyperope, who is obliged to use at infinity an amount of accommodation equal to his hyperopia, this amount must be added to the reciprocal of the distance. Thus, if a person with 2 D. of hyperopia fixes for an object at 50 cm., he uses 2 D. (the reciprocal of .50) plus 2 D. (the amount of his hyperopia) of accommodation. In the case of a myope, whose far point is within infinity, the amount of his myopia must be deducted from the reciprocal of the distance. Thus if a myope of 2 D. fixes for an object at 25 cm., he uses 4 D. (the reciprocal of .25) minus 2 D. (the amount of his myopia) of accommodation.

The preceding paragraph states the case theoretically. As a matter of fact, experience has shown that, even when allowance has been made for the excess or deficit due to refractive error, the amount of accommodation exercised by a hyperope for a given near point is always somewhat in excess of normal, and that exercised by a myope somewhat short of normal. The probable reason for this will be found discussed elsewhere.

MEASURING AMPLITUDE OF ACCOMMODATION.

It will be seen that, for the practical purposes of optometry, it is highly important to be able to measure the amplitude of accommodation, for with this information in our possession

we are able to make valuable deductions both as to the state of the patient's refraction, and also as to the efficiency or otherwise of his accommodative powers.

The very simple and obvious mathematical premise which lies at the basis of all our calculations is that the amplitude of accommodation represents the difference between the total dioptric power of the eye and its static refraction, as expressed in the formula

$$a = p - r$$

in which a stands for amplitude, p for total dioptrism, and r for static refraction.

Proceeding to the practical problem of determining the value of r, we note that the static refraction of the eye is the reciprocal of the far point, or punctum remotum, represented by the letter R, as expressed in the formula

$$r = \frac{1}{R}$$

and that the total dioptrism of the eye is the reciprocal of the near point, or punctum proximum, represented by the letter P, as expressed in the formula

$$P = \frac{1}{P}$$

Thus, if the patient's near point prove to be 10 cm., then his total developed dioptrism is 100/10 or 10 D. If his far point be infinity, then his static refraction is 100/inf., or O D. Then, according to the formula, 10 D. — O D. = 10 D., which represents his amplitude of accommodation. If his near point be 10 cm. and his far point 50 cm., then his total will be 100/10, or 10 D., his static 100/50, or 2 D., and his amplitude 10 D. — 2 D. = 8 D.

DETERMINING THE FAR POINT.

Inverting the second of the above formulae so as to make R the quantity sought, we have

$$R = \frac{1}{r}$$

but as r, representing the static refraction of the eye, is in practice usually the very thing that we are ultimately seeking

to determine, this presentation of the problem has not much working value. We must look for other, more constructive methods of determining R.

Subjectively we can ascertain the patient's far point with some degree of near-accuracy by means of his ability to read at a given distance (usually at 6 meters, which is optical infinity) test letters so constructed as to subtend on the retina the minimum visual angle at that distance, provided the distance in question represents his far point. If it be less than his far point, the letters will subtend a greater than the minimum visual angle; if it be further than his far point, it will subtend less than the minimum angle. Hence, the smallest sized type he is able to read at the given distance, or, what is the same thing, the distance at which he is just able to read a given size of type, furnishes us an approximation of his far point. The principle of these letters (known as Snellen's letters) and the method of using them, will be found fully discussed elsewhere.

A much more accurate method of determining the far point is the objective method, by means of the retinoscope. For details of this instrument and its use the reader is referred to the section on Retinoscopy. It will here be assumed that he is familiar with the technique. If, then, we place a strong plus lens before the patient's eye, and find the point of reversal, that point will represent the far point of the patient's eye plus the lens. We have only to calculate and throw out, in terms of its reciprocal, the distance represented by the lens, and the remainder represents, also in terms of its reciprocal, the far point of the eye alone. Reducing it to a formula, if f stands for the focal length of the lens, f′ for the point of reversal, and R for the far point, then

$$\frac{1}{f'} - \frac{1}{f} = \frac{1}{R}$$

Thus, if we place a plus 4 D. lens before the eye, and find the point of reversal at 25 cm., we have

$$\frac{1}{25} - \frac{1}{25} = \frac{1}{0}$$

showing that the far point is at infinity. Or if, with the same lens, we find the point of reversal at 10 cm., then

$$\frac{1}{10} - \frac{1}{25} = \frac{1}{16.6}$$

showing that the far point is at 16.6 cm.—he is a myope of 6 D. Or, again, if, with the same lens, we find the point of reversal at 50 cm., then

$$\frac{1}{50} - \frac{1}{25} = \frac{1}{-50}$$

indicating that the far point is 50 cm. beyond infinity—the patient is a hyperope of 2 D.

It is true that both these methods are subject to sources of error; but they are the sources of error which pertain to the test-chart and retinoscope in general, and therefore are to be avoided and minimized by whatever modifications of technique render these procedures more reliable in their general outworking.

DETERMINING THE NEAR POINT.

Theoretically, the determination of the near point should be a simpler matter than that of the far point, since (except in presbyopes whose accommodation is lost) the near point is always an actual, discoverable point within infinity. In practice, however, there are many obstacles in the way of an accurate ascertainment of the near point, even more insurmountable than those which pertain to the far point.

For one thing, the near point being a function of active muscular effort, is hardly ever the same in the same patient at any two successive examinations, depending upon conditions of general health fatigue, mental and physical concentration, etc. And, for another, the exercise of accommodation is very largely a matter of habit, so that it is exceedingly difficult to get the patient to put into effect more accommodation than he is in the habit of doing.

Of the subjective methods, the old classical one is the pinhole test of Scheiner. Close in front of the eye to be tested we place a card pierced with two tiny holes, which must not be further apart than the diameter of the pupil. Through these

holes the patient views a very small object (a pin-head) which is gradually brought nearer to the eye. As long as accommodation holds out, the pin will be seen singly; but as soon as the pin gets nearer to the eye than the near-point it will be seen double.

More commonly used in optometrical practice is the test-type method, very similar to the test for the far point, except that in this case we have to find the nearest distance at which the patient can read a given type. For this purpose we employ the Jaeger type, or some modification of it, which is constructed substantially on the same visual angle principle as Snellen's distance type. However, it is much more difficult to approximate accuracy in the case of the near type, for the reason that at such a short distance from the nodal point of the eye very slight changes of distance cause considerable variations of the visual angle, and it is almost impossible to devise a scale of letters which will compensate for this variation.

If we elect this method, we must carry it out as carefully as we can, and avoid sources of error as much as possible.

Moreover, with the exercise of accommodation there is a corresponding exercise of the sphinctre iridis, causing a progressive contraction of the pupil; and this, acting as a cut-off to the peripheral rays of light, has a distinctly modifying effect upon the clearness of the image, quite apart from the clearness of the focus. However, as this and the foregoing "source of error" are both of them normal to the functioning of accommodation, their vitiating effect upon the test is probably academic rather than practical. After all, the reading of small type at near distance is the normal purpose of accommodation; hence this test will probably remain the commonest method of determining the near point.

Another subjective method is to find a concave lens which will serve as a substitute for the accommodation, and make light-waves from infinity as though they came from the near point. The technique of this method is to find first the type on the Snellen chart which represents the patient's far point, and then put before the patient's eye successively stronger minus lenses until he can no longer read this type. The reciprocal

of the strongest minus lens with which he can read represents his near point.

The objection to this method is precisely the opposite of the objection to the near-type test, namely, that under the influence of the minus lenses the visual angle becomes so small that the size of the image made upon the retina prevents the patient from reading the distant type long before his accommodation has been equalized. It is a poor method in practice.

For the near point, as for the far point, the objective method of determination is, on the whole, the most satisfactory when the amplitude of accommodation is in question. The carrying out of this procedure belongs to the technique of dynamic refraction, which is described in detail elsewhere.

Sheard holds that the near point cannot be accurately determined by dynamic skiametry as it is generally practiced. For this purpose he uses the following technique: With full distance correction on, the patient is directed to fix his vision upon a letter chart held two or three inches in front of the mirror, and the operator notes at some convenient point the movement of the shadow. If it is "with" he pushes the chart forward until it becomes "against." He then comes forward with the mirror until it is "with" again; and so on until with the chart some distance in front of the mirror he locates the nearest point of neutral shadow, which denotes the patient's true near point.

CALCULATING THE AMPLITUDE.

Having now determined both the far point and the near point, we divide each quantity into unity to find, respectively, the static refraction and the total developed dioptrism of the eye. If the far point has been shown to be within optical infinity, it is written as a negative quantity, and thus divided into unity; if beyond infinity, it is written as a positive quantity, and thus divided. Thus, if the far point was found to be at 4 meters, the static refraction is —1/4, or .25 D. of myopia. If at 50 cm. beyond infinity, then it is 1/50, or 2 D. of hyperopia.

To calculate the amplitude of accommodation, we then proceed to give effect to our original formula:

$$a = p - r$$

Let us assume that in both the illustrations just cited the near point had been shown to be at 10 cm., making p equal to 10 D. Then, in the first example,

$$a = 10 - (-.25) = 10.25 \text{ D.}$$

and in the second instance,

$$a = 10 - 2 = 8 \text{ D.}$$

and in a case where the far point was demonstrated at infinity (emmetropia) and the near point at 10 cm.,

$$a = 10 - \text{inf.} = 10 \text{ D.}$$

MEASURING RELATIVE ACCOMMODATION.

The importance of ascertaining the amount of the patient's relative accommodation, positive and negative, has already been pointed out. In conjunction with the amount of relative convergence (adduction and abduction) it represents the flexibility of these two functions. The nearer this relative accommodation approximates the normal, the more we can rely upon the patient being able to maintain proper co-ordination between the two and to find his own comfortable near point when rendered emmetropic by distance correction.

Positive relative accommodation is found by gradually adding minus lens power to the eye while convergence is maintained for a near point. Negative accommodation by gradually adding plus lens power under like conditions. When vision blurs, in each case, the limit is reached. Sheard holds that dynamic skiametry, as generally practiced, is but a method of determining negative relative accommodation.

According to Donders, "The accommodation can be maintained only for a distance at which, in reference to the negative part, the positive part of relative accommodation is tolerably large." If, therefore, the result of the test does not fulfill this condition—i. e., if the positive relative accommodation is not noticeably greater than the negative—we are justified in assuming that there is lack of flexibility, and that the eyes cannot long maintain accommodation for the point in question. The best distance at which to make the test is the distance at which the patient ordinarily does his or her near work.

MEASURING ACCOMMODATIVE RESERVE.

The measurement of the negative relative convergence is, in effect, the measurement of the accommodative reserve; or, to be accurate, it furnishes the basis for its calculation. The closest point at which we can get neutrality of shadow is the comfortable near point. Converting this into dioptres (by dividing it into unity) gives us the maximum amount of accommodation that the patient can use without eye-strain. Deducting this from the total amplitude of accommodation, we obtain the reserve accommodation required by this patient at that point.

The ratio between the three factors—the total amplitude, the near point, and the required reserve—indicates the flexibility of the accommodation. Normally, the near point, in terms of dioptrism, should be about three or four times as much as the required reserve. If this ratio be markedly disturbed, accommodative insufficiency or inefficiency is indicated.

THE COMFORTABLE NEAR POINT.

It is formally assumed that two-thirds of the amplitude of accommodation can be exercised for close work for reasonably long periods of time without inconvenience or discomfort; in other words, that it is always sufficient to have one-third in reserve at the near-point. Accommodation being a dynamic, muscular function, however, individuals differ in this respect. There is, undoubtedly, a comfortable near point for each individual, which should be sought for and determined in every case.

One method of finding this comfortable reading point is by dynamic retinoscopy. With the distance correction in place, we begin to shadow dynamically at 1 meter, or 40 inches. If the movement of the shadow is not with the mirror, we take the mirror in nearer to the patient's eye until it is seen moving with. We then back off until the shadow is abolished. This point represents the near point of comfortable vision, for this is the point at which the eye naturally harmonizes its accommodation and its convergence.

Another method is the cross-cylinder of R. M. Lockwood. After the refractive error has been corrected, and the near vision checked by appropriate near type which the patient

reads clearly, a compound lens equivalent to a cross-cylinder, say a plus .50 sphere and a minus 1 cylinder (which is equivalent to cross-cylinders of .50 each) is put before the eye, creating a false astigmatism of .50 hyperopic in one and .50 myopic in the other. The type will blur, but if for the type there is now substituted a T chart, with the arms of the T made to coincide with the axes of the false astigmatism, then, if before applying the test the eyes were in exact focus there will be no perceptible difference in the two arms of the T; but if the focus was not exact, then the test will show a difference, and the spherical part of the correction must be altered until this difference is not perceptible.

The efficiency of the cross-cylinder test can be increased by having a set of, say, three T charts of different sizes. The cross cylinders being applied, as described above, the smallest T chart should be brought close to the eye and slowly withdrawn until both lines become equally clear. If this does not occur by the time a distance say of 12 inches is reached, substitute the second T chart out to about 24 inches, and then the larger chart to about 40 inches until the point of equalization is found. Converted into dioptres, this gives the comfortable amplitude of accommodation.

SUMMARY.

Recapitulating, the investigation of the patient's accommodative status involves the following practical steps:

1. Ascertain the patient's far point. This is equivalent to determining the static refraction of the eyes, and is to be done by the usual methods, viz., Snellen's test types, subjectively, and static retinoscopy, objectively. The far point may be found to differ in different meridians of the eye (astigmatism).

Having found the far point, if it denotes an error of static refraction, it is best to correct this error, thus making the patient emmetropic, with a far point at infinity, before proceeding to further tests.

2. Ascertain the near point. This is to be done in various ways,—by Scheiner's two-hole test, by Jaeger test types, by minus lens power with which the patient can read 20/20, or

by dynamic skiametry, Sheard's method. Of these, the last named is undoubtedly the most accurate.

Having found the near point, subtract the far point from it, in terms of dioptrism, to find the amplitude of accommodation.

3. Make a still finer test of the patient's accommodative efficiency by means of Lockwood's cross-cylinder method.

4. Test out the patient's relative accommodation by the addition of minus and plus lenses, respectively, at near point. Especially explore the negative relative accommodation, for the purpose of determining the amount of reserve necessary in his case.

5. On the comparative results of all these data decide as to the desirability, or otherwise, of assisting the patient's near vision, without regard to any stereotyped rules of practice.

ANOMALIES OF ACCOMMODATION.

Within reasonable limits the above tests will give us approximately the available amplitude of accommodation, or, at least, the amplitude which the patient activates. This will coincide with the real total amplitude only when there exist no modifying conditions which prevent the free interplay of the various elements in the equation. If the amplitude, as determined by the tests, measures up to what is to be expected at the patient's age, we may assume that no such vitiating conditions exist. If not, we must assume, on the contrary, the presence of some anomaly of accommodation, and apply further tests in a search for the trouble.

CILIARY SPASM.

Commonest among these accommodative anomalies is a periodic (clonic) or a permanent (tonic) contraction of the ciliary muscle, which frequently occurs in hyperopia, and which results in a certain amount of locked accommodation that is not easy to demonstrate by any of the methods described above.

Subjectively, such a patient's far point would register inside of its mathematical range, because he is not able to attain complete ciliary relaxation. It may register at infinity, in which case he will appear, so far as his far point is concerned,

to be emmetropic; or it may even be within infinity, so that a hasty conclusion would set him down as a myope.

The capital symptom of all anomalies of accommodation, naturally, is a discrepancy in the relative positions of far point and near point. The nature of the discrepancy is a guide to the nature of the anomaly. In hyperopic spasm of the ciliary, the far point is, as just explained, either at infinity or even within infinity, while the near point is considerably further out than normal. This, coupled with symptoms of accommodative asthenopia, leads us to suspect the presence of a ciliary spasm.

The proof of the existence of the spasm lies in inducing the patient to surrender all or part of it, thus demonstrating it. There are several ways of doing this, all of which will be found fully discussed in the section devoted to hyperopia. Patients can usually be made to relinquish all of a clonic spasm, and a portion of a tonic spasm.

ACCOMMODATIVE INSUFFICIENCY.

This condition, of course, is normal at and after the age of 45, when it goes by the name of presbyopia. It is only when it is found in younger persons, and when in presbyopes the insufficiency exceeds the amount proper to their age, that it is regarded as an anomaly, and is known as accommodative insufficiency, or subnormal accommodation.

It is a little difficult to draw a hard and fast line between insufficiencies due to actual paralysis, complete or partial (paresis) of the ciliary muscle, and those that are functional. Some, of course, belong entirely in the former class, and are then to be regarded, not as cases of insufficiency, but of paralysis or paresis, and will be discussed under that heading. Others belong just as definitely in the purely functional class, where no lesion exists, but the trouble is in a faulty innervation of the muscle. Still others constitute a sort of borderland group (e. g., neurasthenia) in which it is hard to say whether the trouble is functional or toxic—perhaps a mixture of both In a large proportion of cases it seems impossible to assign any definite cause at all.

The prime symptom is naturally an inability to see at a convenient near-point—premature presbyopia, or (in case of an older person) excessive presbyopia. The near point, as in

ciliary spasm, is considerably further out than normal. Investigation shows a contraction of the range, and diminution of amplitude, of accommodation. The tests for ciliary spasm reveal none. Relative accommodation is either lacking or much reduced. Attempts to force accommodation fail. There is, however, no trouble until the patient's near point is reached.

ACCOMMODATIVE INEFFICIENCY.

This condition is to be carefully distinguished from insufficiency. Its existence and importance is of comparatively recent recognition. It consists, essentially, not in any lack of muscular or nervous power, but in an inability to use them properly. Many persons, for some reason or other, never achieve their own potential near-point; others never attain a comfortable relative co-ordination between accommodation and convergence, and therefore cannot (or do not) hold a near-point long when they find it. Apparently no definite cause can be assigned. It seems to be simply a faulty habit of functioning.

These are the cases which, above all others, call for thorough investigation of the accommodation-convergence relation, positive and negative relative accommodation, and accommodative reserve, and whose treatment taxes the judgment of the refractionist. Needless to say that accurate distance correction, where needed, is of great importance; although, to be sure, many of these cases of inefficiency are found in emmetropes. Emmetropia being present, or being brought about by distance correction, inefficient accommodation must be acknowledged when a patient proves to have sufficient amplitude but cannot use it at near point without eyestrain.

As to the treatment of such cases, that is a matter of exceedingly nice judgment for the operator. They need some kind of help. No doubt the best kind of assistance, if practicable, is indirect assistance, which will induce proper co-ordination between accommodation and convergence. But if necessary, the refractionist need not hesitate to give reading lenses. The idea that reading addition must not be given to young persons belongs to a by-gone period.

The situation in regard to accommodative inefficiency is best summed up in Lockwood's formulary:

1. The exact functioning of accommodation depends upon a perfectly balanced innervation of the ciliary.

2. Emmetropia is merely the zero of ocular refractive measurements, and has no relation to ciliary innervation.

3. There are no sure methods of detecting faulty ciliary innervation at a distance.

4. It is readily detected at near point by several methods. (The best are dynamic skiametry and his own cross-cylinder test.)

5. Glasses, to be comfortable, must be such as to produce balanced ocular innervation.

Accommodation, Line Of. The distance in space along which there is clear vision of an object, in spite of the disparity of the retinal points. This distance depends upon the width of the pupil, the visual acuity, and the dioptrism of the eye.

Accommodometer. See **Punctumeter.**

Achloropsia. Inability to distinguish the color, green. A technical term for green-blindness.

Achromatism. Absence of chromatic aberration. (See **Aberration.**) Such a state is only relative, as absolute achromatism is impossible of attainment.

Achromatic lenses are made by the admixture of two kinds, or more, of glass, having different optical properties, each of which counteracts to a great extent the chromatic aberration of the others.

Achromatopsia. A technical term for color-blindness.

Actinic. In the white beam of light, mostly, but not altogether, beyond the violet, are certain waves or rays which, falling on the retina, do not register the sensation of vision, but exercise a chemical action upon the structures of the eye. These are called actinic rays. The precise nature of their action is unknown, but it is understood to be irritant, and it is now well established that these rays play a primary role in the production of cataract, not by their direct action upon the crystalline lens, but, being dispersed by the fibres of the lens, they are reflected and refracted against the ciliary body, whose function they impair, thus depriving the lens of its nutriment.

Many attempts have been made to construct lenses which will absorb the actinic rays and prevent their entrance into the eye. As they are mostly in the upper part of the spectrum, such lenses are mostly made to keep out the violet and ultra-violet rays, and are therefore usually of a yellow or amber color. The Crookes lens is a conspicuous and successful example of this type of lens.

Actinism. The effects of actinic rays upon the eyes.

Acuity. In optics this word has two applications. As applied to an image it indicates the sharpness and clearness with which the details are outlined. As applied to the function of vision, it signifies the keenness with which the retinal image is perceived (visual acuity).

The acuteness of an image depends upon the perfection with which it is focussed, and the nice balance of illumination. (See **Image.**)

Visual acuity is a physio-nervous attribute, made up of two elements, viz., the peripheral element, i. e., the sensibility of the rods and cones to light stimulus, and the central element, i. e., the reaction of the brain to transmitted impulses. The latter element is assumed to be constant in all normal individuals. The test of visual acuity, therefore, is in reality a test of the integral state of the retinal rods and cones. In order for two points of light to be perceived as two separate points (which, of course, is the basis of the perception of the details of an image), their respective foci must fall on separate rods and cones. For this, again, it is necessary that the foci be separated by an angular distance of at least 1 minute (minimum visual angle). A test of visual acuity, therefore (i. e., of ability to distinguish details of a letter, picture, etc.) under the minimum visual angle, determines with the greatest degree of accuracy the integrity of the rods and cones. If there be diseased rods and cones sprinkled among the healthy ones some of the points of light will focus on these and vision will be indistinct.

Two common errors should be noted here. First, despite our assumption, the reaction of the brain to an image is not alike in all normal individuals. Like every other brain reac-

tion, it depends largely upon training. An Indian has better visual acuity than a civilized man, not because he has a better retina, but because his brain is trained to react better to images. The same difference, in lesser degrees, obtains between individuals of the same race. In certain unusual conditions it obtains in very marked degree. (See **Amblyopia Ex Anopsia.**) Second, the so-called "visual acuity test" which every refractionist makes and records as a preliminary to his examination is not a test of the visual acuity at all, but of the visual angle. If the minimum visual angle is larger than it ought to be (as evidenced by the V/v fraction), it may be due to an error of refraction or to a genuine lowered visual acuity. Only when the inability to read the proper test type has been shown not to be due to an error of refraction does such a test furnish a real indication and measure of the visual acuity.

Adaptation of the Retina. The faculty of the retina of adapting itself to variations in intensity of light. Adaptation from dark to light is called "light adaptation"; that from light to dark, "dark adaptation." Sudden, marked changes require an appreciable time for such adaptation to be made, as everyone knows by common experience. Diseases of the retina and those which interfere with the action of the retina, inhibit this faculty.

Adduction. In general, this term signifies the turning of the eyes inward from parallelism toward the median line by the internal rectus muscles—the muscular mechanism of convergence. No doubt the obliques assist in the act, but they are not essential to it. It is a voluntary act, but as ordinarily performed is subconscious, and is stimulated byaccommodation and the fusion center.

Technically, the word has come to be applied to the artificial exercise of the internal recti, without the associated function of accommodation, by means of prisms, base out, by placing stronger and stronger prisms before the eyes, while the patient tries to maintain single vision of a small object at infinity, the internal recti are brought into play to the limit of their ability, while no accommodation is exercised. Adduction seldom develops more than about 24 prism dioptres of power in

the internals, whereas natural amplitude of convergence in a normal person is usually more than 30 prism dioptres.

Advancement. An operation for the cure of squint, in which the longer muscle or tendon of the squinting eye is cut and attached to the eyeball at a more anterior point.

After-Images. The effects of retinal stimulation by light last for an appreciable time after the stimulus itself has ceased, giving rise to what are known as after-images. These effects consist in (a) a continuation of the primary action of the stimulus, in accordance with the principles of inertia, prolonging the perception of the original image, and (b) the reaction of fatigue, due to exhaustion of the stimulated substance in the retina, giving the sensation of an image in which the relations of light and shade and color are inverted. The former result is known as a positive, and the latter as a negative, after-image.

Thus, we see a rising rocket as a streamer of light, because the infinite series of luminous points made by the rocket in its movement upward make upon the retina a corresponding series of stimulations which persist after the rocket has passed these points, producing an infinite linear series of positive after-images. It is for the same reason that when a revolving wheel or top reaches a certain speed it no longer appears to move; the revolving spokes or segments successively stimulate rods and cones of the retina which are still reacting to the positive image of the previous spoke or segment, so that the sensation is of one continuous image.

In after-images, it is often possible for the eye to perceive detail which escaped notice in the primary stimulation on account of excessive brightness. Thus, if one looks at a tree standing between himself and bright sun, he cannot perceive the small branches or twigs; but on closing the eyes, these become visible, because as the image fades the chiaroscuro relations are changed, and the intensity is moderated.

If the object viewed is not very bright, and is looked at for several seconds, the positive after-image is hardly perceived, but the negative after-image immediately presents itself. As stated the light and shade relations are reversed, as in the nega-

tive of a photograph-film, and in normal cases the colors in the after-image are the complementaries of those in the original image. It is noteworthy, however, that red images may give positive after-images which are complementary in color.

The apparent size of an after-image depends upon the distance to which it is projected, due, of course, to the fact that a small near object stimulates the same area of the retina as a larger object further away, and vice versa.

Normally, after-images are not noticed, in accordance with the physiological law that we attend only to those things which interest us. It is a matter for the judgment of the examiner, how far after-images and entoptic phenomena are normal.

Albinism. A condition in which, in consequence of some biologic defect, the dark coloring matter or pigment is absent from the skin, hair and eyes. The skin is milky, the hair white, the iris pale rose color, and the pupil intensely red because the absence of pigment allows the blood-vessels to be clearly seen. The eyes of albinos are naturally not adapted to bright sunlight, but see best in the shade or in the moonlight. There are conditions of partial albinism.

Alexia. The word denotes inability to read, by which is meant not illiteracy, but some defect in the reading faculties. It may be of one of two kinds: (1) inability to recognize the word-images, due to a lesion between the occipital and frontal lobes of the brain, or (2) inability to associate the word-pictures, due to disease of the frontal areas of the brain.

Amacrine. A uni-polar nerve-cell found in the retina.

Amaurosis. Absolute blindness, from whatever cause, as distinct from amblyopia, which denotes relative defect of vision.

A special application of the word is found in the term Amaurotic Family Idiotcy, a rare affection of the retina which occurs in young children during the first two years of life. The area of the macula is occupied by a grayish-white patch, about as large as the optic disc, with a red spot in the center. The rest of the fundus is usually normal. These patients gradually become blind, and within a few months die. The cause

of the disease is unknown. It attacks, most often, the children of Jewish parents.

Amblyopia. The word actually means blindness, but it is used to signify loss of vision, partial or complete, in which no organic change can be discerned in the retina.

The commonest form of amblyopia is that due to disuse of the eye. For some reason, usually to avoid diplopia in strabismus, the patient has learned to disregard the image in one of the eyes, and the brain has therefore ceased to react to the image, (Amblyopia ex anopsia). By persistent and properly directed exercises of the eye this form of amblyopia can often be overcome. (See **Amblyscope.**) A simple measure of cure is to cover the sound eye for long periods at a stretch, and force the patient to use the amblyopic eye.

Another form of the disorder is toxic amblyopia, due to excessive smoking, drinking, etc., in which the rods and cones of the retina become temporarily paralyzed. Drugs, such as quinine, also occasionally cause it. It is usually central, manifesting itself as a central scotoma. Abandonment of the thing that causes it will often result in restoration of vision.

A third common form is hysterical amblyopia, seen chiefly in women. This form comes on, as a rule, very suddenly, and, after lasting for a variable length of time, disappears just as suddenly.

Amblyoscope. An apparatus for the re-education of the vision in amblyopia ex anopsia. The Worth-Black is the standard form of amblyoscope. It consists essentially of two eye-

The Worth-Black Amblyoscope.

pieces, similar to an opera glass, which can be turned on a swivel to adapt themselves to any degree of convergence. At the end of each tube is mounted a different picture card, which together make up a composite scene, (e. g., a bird on one card and a bird-cage on the other). To begin with, the picture corresponding to the amblyopic eye is highly illuminated, the other one very poorly, so as to draw attention to the image on the amblyopic retina. The patient tries to bring the two images into fusion (e. g., to place the bird in the cage), thus exercising both covergence and attention faculty at the same time. Gradually, the illumination of the two images is equalized, until the patient can see both images equally well with equal illumination.

Ametropia. A general term applied to that condition of the eye in which there is an error of refraction of any kind.

Amotio Retinae. Detachment of the retina.

Amphiblestritis. Another term for retinitis.

Amphodiplopia. Diplopia in both eyes.

Amplitude of Accommodation. The total amount of dioptric power which the eye is capable of adding to itself by the maximum contraction of its ciliary muscle. (See **Accommodation.**)

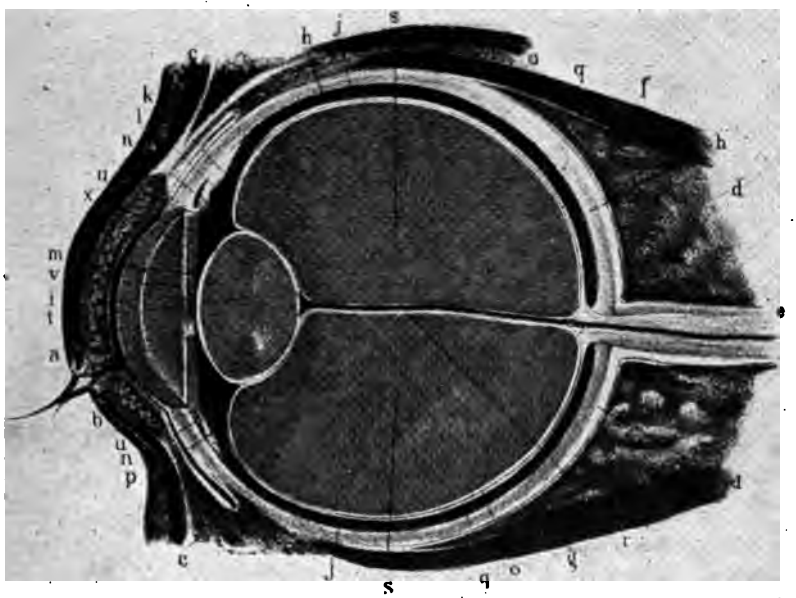
Amplitude of Convergence. The total amount of deviation inward from the median line which the eyes can make by maximum contraction of the internal rectus muscles. (See **Convergence.**)

Anacamptics. The study of reflection of sound or light.

Anaphoria. Tendency of the eyes to turn upward. See **Heterophoria.**

Anatomy of the Eye. The eye is a hollow spherical globe, made up of three coats, or tunics, hereafter to be described. Each eye is set in a pyramidal cavity in the upper frontal part of the skull made by the union of seven of the cranial bones, namely, the frontal bone, the sphenoid, the ethmoid, the superior maxillary, the malar, the lachrymal, and the palatine.

Three of these, the frontal, ethmoid, and sphenoid, being central portions of the skull, are common to both orbits; so that, in reality, the two orbits are composed of eleven bones only.



From Hirschfeld's Charts.

a. Superior eyelid.—b. Posterior eyelid showing its different layers.—c, c. Reflection of the conjunctiva on the posterior face of the eyelid, and on the anterior face of the ocular globe.—d. d. Orbito ocular aponeurosis, prolonged on, e, the sheath of the optic nerve, and on the sheaths of the muscles.—f. Superior rectus, and g, Inferior rectus.—h, h. Sclerotic coat thickened posteriorly by the sheath of the optic nerve, and anteriorly by the expansion of the aponeurosis of the recti muscles.—i. Transparent cornea cut to show its laminated texture.—j, j. Choroid coat.—k. Ciliary circle—l. Ciliary bodies and processes.—m. Iris and pupil.—n, n. Canal of Fontana.—o, o. Retina, continuous with the substance of the optic nerve.—p. Ciliary circle of Zinn.—q. q. Hyaloid membrane.—r. Capsular artery lodged in the hyaloid canal.—s, s. Vitreous humour and its cells.—t. Crystalline lens and its capsule.—u, u. Ruffled canal, or, Canal of Petit.—v. Anterior chamber.—x. Posterior chamber.

The bases, or large openings, of the orbits, look toward the front; the apices look backward and slighly inward. At the apex of each orbit, toward the nasal side, is an opening, or foramen, about 5 mm. in diameter, known as the optic foramen, through which the optic nerve and the ophthalmic artery emerge from the cranium to enter the eye. This is the largest of the orbital foramina, of which, however, there are eight others, transmitting nerves and blood-vessels as follows:

Spheno-maxillary fissure: Superior maxillary nerve, infra-orbital vessels, and ascending branches of the spheno-palatine or Meckel's ganglion.

Sphenoidal Fissure: Third, fourth, three branches of the ophthalmic division of the fifth, and sixth cranial nerves, some filaments of the sympathetic, the orbital branch of the middle meningeal artery, and the ophthalmic vein.

Supra-orbital Fissure: Supra-orbital artery, vein and nerve.

Anterior Ethmoidal Foramen: Anterior ethmoidal vessels and nasal nerve.

Posterior Ethmoidal Foramen: Posterior ethmoidal vessels.

Infra-orbital Fissure: Infra-orbital artery, and vein.

Malar Foramen: Nerves and vessels of the orbit.

THE EYEBALL.

The eyeball itself, as stated, is made up of three coats, or tunics, one outside the other, each having substantially a hollow spherical form, as follows:

(1) Inner, or nervous, coat. This consists of a flaring of the optic nerve into a layer of nervous elements, extending forward about two-thirds of the eyeball, and forming the retina.

(2) Middle, or musculo-vascular coat. This coat is comprised of muscle tissue and vessels; it starts at the circumference of the optic nerve where it enters the eye, extends slightly more forward than the retina, and consists of three portions, (a) the chorioid, (b) the ciliary body, and (c) the iris.

(3) Outer, or supporting tunic. This is composed of thick, firm, white fibrous tissue, beginning at the optic nerve and extending some four-fifths of the eyeball, to the circumference of the cornea. It gives form and shape to the eyeball, being known as the sclera.

Considering the eye as a camera, the inner coat, or retina, may be regarded as the sensitive film, the middle coat as the cut-off and shadow apparatus, and the outer coat, or sclera, as the dark box. Detailed descriptions of each of these elements of the eye will be given later on.

CAPSULE OF TENON.

The larger part of the eyeball is covered by a delicate membrane, from the optic nerve to within a few millimeters of the

corneal ring, called the Capsule of Tenon; it is also known as Bonnet's capsule.

CONJUNCTIVA.

The anterior portion of the eyeball, i. e., the portion that is visible, is covered externally by a thin, transparent mucus membrane, called the Conjunctiva. This membrane is continuously reflected over the eyelids, so as to form a sac. The part that covers the eyeball is known as the bulbar conjunctiva, that which lines the lids as the palpebral conjunctiva. The fold between the two is called the conjunctival fornix, upper and lower respectively.

An extremely thin layer of the conjunctiva is continued over the cornea, as a protection to that tissue, and is known as the corneal conjunctiva.

SCLERA.

The sclera, or sclerotic,—the outer coat, which gives shape and support to the globe, is composed of connective tissue. It is firm and white, and relatively thick, especially at the back; and to it are attached the extrinsic muscles of the eyeball.

CORNEA.

Set into the front part of the sclera, much as a crystal into a watch, is a transparent membrane, called the cornea, forming the front window of the anterior chamber. It consists of five layers, from without in as follows:

Epithelium.
Bowman's Membrane.
Cornea Proper.
Descemet's Membrane.
Endothelium.

The cornea is not furnished with blood-vessels, as these would impair its transparency, but is richly supplied with nerves from the fifth cranial and sympathetics. Its function is to serve as a refracting medium for the light which enters the eye.

A detailed description of this important membrane will be found under the heading of **Cornea.**

The circumferential ring representing the junction of cornea and sclera is called the limbus, or sclero-corneal junction. Im-

mediately outside this ring, in the deep scleral tissue, is a circular lymphatic canal, called the canal of Schlemm.

CRYSTALLINE LENS.

A few millimeters back of the cornea, within the eye, fronting the cornea in a vertical position, is a small, transparent lentil-shaped body, the crystalline lens. Its function, also, is a refractive one. It is bi-convex, the back surface being more convex than the front, and is composed of concentric layers of elastic fibre, contained in a capsule. In youth its elasticity is considerable, enabling it to increase its convexity in the act of accommodation, but its elasticity gradually diminishes during life and the power of accommodation proportionately decreases, until both are entirely lost.

The lens is attached to, and held in place by, a fine circular membrane (wrongly termed a ligament), formed by a reflection of the hyaloid membrane, known as the zonula ciliaris. It is also called the zonula of Zinn, and the suspensory ligament. In the folds of this zonula is supposed to be a circular canal, known as the canal of Petit. Like the cornea, the lens has no blood vessels.

For further details of this structure see **Lens, Crystalline.**

ANTERIOR CHAMBER. AQUEOUS HUMOR.

The space between the cornea and the crystalline lens is termed the anterior chamber of the eye, and is filled with a transparent fluid, called the aqueous humor. The aqueous humor is virtually water with a few salts in solution, whose optical density is 1.333, and constitutes one of the refracting media of the eye.

IRIS.

Suspended in the aqueous humor, just in front of the crystalline lens, is a circular musculo-vascular curtain, called the iris, dividing the anterior chamber into two sections. Some anatomists call these two divisions the anterior and posterior chamber, respectively.

The iris is really a portion of the ciliary body, from which it springs. In its centre is a circular aperture, called the pupil, through which light enters the eye. It has two sets of muscles, circular and radiating; contraction of the former diminish the

size of the pupillary opening, contraction of the latter enlarges it. The iris is richly supplied with blood by the ciliary vessels, which anastomose with the conjunctival vessels. It is also the seat of pigment which gives the eye its distinctive color—hence the name, iris. In health it has a beautiful lustre, which is lost in disease.

The function of the iris is that of a diaphragm, or cut-off, to regulate the amount of light entering the eye.

Around its circumferential edge it meets the cornea, the angle thus formed being known as the iritic angle.

CILIARY BODY.

The middle part of the second tunic of the eye is called the ciliary body, because of the hair-like appearance of its striata. It consists of the orbicularis ciliaris, which is hardly distinguishable from the chorioid, the corona radiate, a ruff around the edge of the iris, the ciliary glands, and the ciliary muscle.

The latter is a sphincter muscle surrounding the crystalline lens and attached to the chorioid. Its contraction, according to Helmholz, draws forward the chorioid, relaxes the tension of the zonule, and allows the lens to assume a more convex form (accommodation).

The ciliary is plentifully supplied with blood through the ciliary vessels, and with nerves from the fifth cranial and the sympathetics. (See **Ciliary Body.**)

VITREOUS.

The large space between the crystalline lens and the retina, constituting about four-fifths of the globe, is filled with a transparent, gelatinous mass, consisting of a clear liquid enclosed in the meshes of a reticulum, called the vitreous humor, because of its optical resemblance to glass. In the fetus it is traversed by an artery, the hyaloid artery, piercing it centrally from retina to lens, but after birth this artery disappears, leaving a canal known as the central or hyaloid canal. (Occasionally the artery persists after birth.) In extra-uterine life the vitreous is destitute of vessels and nerves. Probably the hyaloid canal serves as a lymph channel.

The vitreous serves as a further refracting medium of the eye, having an optical density of 1.336.

RETINA.

Spread out over the inner surface of the choroid is a thin, transparent membrane, consisting of a flared continuation of the optic nerve, which serves as the sensitive film for the camera of the eye. This is the retina. It is made up of ten layers, from within outward as follows:

Internal limiting membrane.
Fibrous layer (nerve fibres).
Vesicular layer (nerve cells).
Inner molecular layer.
Inner nuclear layer.
Outer molecular layer.
Outer nuclear layer.
External limiting membrane.
Layer of rods and cones (Jacob's membrane).
Pigmentary layer.

The layer of rods and cones represents the spread-out ending of the optic nerve. A little to the temporal side is the small, circular spot, devoid of vessels but rich in nerve-endings, where vision is the keenest, known as the yellow spot, because of its color, or the macula lutea. In the centre of the yellow spot is a still more sensitive spot called the fovea centralis.

The retina is attached to the choroid only at the optic disc and at the anterior border. At the latter attachment its edge is saw-shaped, and is known as the ora serrata. It is plentifully supplied with blood through the branches of the central retinal artery, which enters with the optic nerve.

For further description, see **Retina.**

CHOROID.

Immediately underneath the retina lies the choroid, or chorioid, a pigmented and exceedingly vascular membrane consisting of five layers, from within outward as follows:

Suprachoroid, or pigmented epithelium.
Layer of large vessels.
Layer of medium-sized vessels.
Layer of capillaries.
Lamina vitrea, or lamina basalis.

All but the last two layers are richly supplied with pigment substance, which gives the choroid its dark brown color, and

serves to absorb the excess of light falling on the retina. The abundant blood supply, derived from the ophthalmic and ciliary arteries, helps to nourish the retina.

The choroid is attached to the optic nerve, where the latter enters the eye, and anteriorly is continuous with the ciliary body. Since the retina is transparent, it is the chorioid that furnishes the color and substance of the fundus picture seen with the ophthalmoscope.

UVEA.

On account of the similarity of the dark sphere, hanging upon the optic nerve as upon a stalk, to a grape, the middle tunic of the eye has received the name of uvea, or the uveal tract.

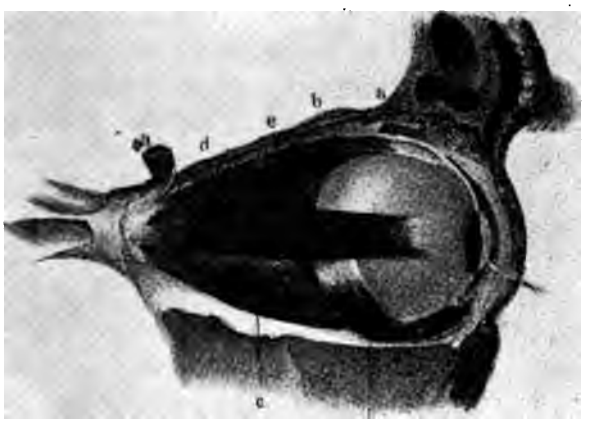
OPTIC NERVE.

A little to the nasal side of the centre of the retina is a light-buff-colored, circular area, about 1.5 mm. in diameter, where the optic nerve enters the eye. It is known as the optic disc, or papilla, and is itself insensible to light stimulation; hence it is also called the blind spot. The disc is one of the chief landmarks of the fundus in ophthalmoscopy. (See **Disc, Optic.**)

The optic nerve, consisting of fibres gathered up from the two lateral halves of the retina, goes backward to the optic chiasm, where the fibres from each temporal half cross over to the other side. From that point on, the lateral half of each retina is represented on the corresponding side of the brain. Thence the tract proceeds backward to the quadrigeminal and geniculate bodies, where the fibres terminate and deliver their impulses to a new set. The new tract conveys the impulses to the temporal lobe on each side, whence they are relayed by another set of nerve fibres to the left frontal lobe of the brain. (See **Optic Tract.**)

MUSCLES.

The eye has two sets of muscles: (1) the extrinsic muscles, which are on the outside of the eyeball, and execute the rotary movements of the globe, and (2) the intrinsic muscles, which are inside the eyeball, and are concerned in the visual functioning of the eye.



From Hirschfeld's Charts.

a, a Levator palpebrae superior.—b. Superior rectus.—c. Inferior rectus.—d. External rectus.—e. Internal rectus.—f. Inferior oblique. All these muscles in the ocular globe are viewed in profile

All of the extrinsic muscles have their attachment on the bony orbit, and are inserted in the sclera at convenient points for accomplishing the movements required of them, as follows:

Internal rectus. Insertion: About 5.5 mm. from the inner margin of the cornea, on a horizontal line drawn through the centre of the cornea. Function: Rotates the eyeball inward.

External rectus. Insertion: About 7 mm. from the outer margin of the cornea on a similar line. Function: Rotates the eyeball outward.

Superior Rectus. Insertion: About 7.5 mm. from the upper margin of the cornea, on a vertical line drawn through the centre of the cornea. Function: Rotates the eyeball upward.

Inferior rectus. Insertion: About 6.5 mm. from the lower margin of the cornea on a similar vertical line. Function: Rotates the eyeball downward.

Superior oblique. Insertion: In the vertical meridian of the eyeball, behind the equator. This muscle arises from the upper and inner margin of the orbit, and passes through a pulley (trochlea), after which the tendon bends sharply backward at an acute angle, and passes under the superior oblique to the eyeball. Function: Rotates the eyeball so that the upper end of the vertical meridian tilts inward, and abducts it.

Inferior oblique. Insertion: On the outer side of the eyeball, behind the equator. This muscle arises from the lower and inner margin of the orbit. Function: Rotates the eyeball in a precisely opposite fashion to the superior oblique.

The internal and external recti of the two eyes act in pairs, to rotate them inward and outward, respectively, in equal degrees. The action of the internal recti is modified by the inferior obliques, so that when the eyes turn inward they also turn downward obliquely; that of the external recti is modified by the superior obliques, so that when they turn outward they also turn obliquely upward. In conjugate deviation of the eyes, i. e. when both turn in the same direction, one internal and one external rectus act in concert.

All the extrinsic muscles are innervated by the third cranial nerve, except the external rectus, which is supplied by the sixth, and the superior oblique, which is supplied by the fourth nerve.

With the exception of the internal and external recti, whose action is directly horizontal, each eye-muscle has a main and a subsidiary action, concerning which it may be said that the main action increases as the subsidiary decreases, and vice versa, and that the main action increases in one special direction of the gaze.

	Main Action	Subsidiary Action
Superior Rectus	Moves eye up; action increases as eye is turned out; becomes nil when eye is turned in.	Adducts eye and rotates vertical meridian inward; action increases as eye is turned in. Raises upper lid.
Inferior Oblique	Moves eye up; action increases as eye is turned in; becomes nil when eye is turned out.	Abducts eye and rotates vertical meridian outward; action increases as eye is turned out.
Inferior Rectus	Moves eye down; action increased as eye is turned out; becomes nil when eye is turned in.	Adducts eye and rotates vertical meridian out; action increases as eye is turned in. Pulls down lower lid.
Superior Oblique	Moves eye down; action increases as eye is turned in; becomes nil when eye is turned out.	Abducts eye and rotates vertical meridian in; action increases as eye is turned out.

The internal and external recti are perfect antagonists. The superior and inferior recti are antagonists vertically, but synergists laterally, both adducting the eye. The superior and inferior obliques are antagonists sagitally, but synergists laterally, both abducting the eye.

In addition to these extrinsic muscles of the eye itself, there are the levator palpebrae, which arises from the orbit and is inserted in the tarsus of the lid, and whose function is to raise the lid; and the orbicularis palpebrae, arising from the superior maxillary bone and inserted in the tarsus, whose function is to close the eyelid. The former is innervated by the third, the latter by the seventh, cranial nerve.

The intrinsic muscles are the ciliary muscle and the muscles of the iris. The ciliary muscle surrounds the crystalline lens, and is a sphinctre muscle. Its contraction increases the convexity of the lens, thus performing the mechanical part of accommodation. It is innervated by the third cranial nerve, through the short ciliary fibres of the sympathetic.

The iris has two sets of muscles, the concentric, or sphincter, and the radiating muscles. Contraction of the former draws the iris toward the centre, like the shirr-string, making the pupillary opening smaller; contraction of the latter pulls the iris back toward its circumference, bunching it on itself, as when we draw a curtain back, making the pupillary opening wider. The circular muscles are innervated by the third cranial nerve; the radiating muscles by the sympathetics.

NERVES.

Six out of the twelve cranial nerves go to, and innervate, the eye and its appendages. All these nerves, with the exception of the optic nerve, have their origin, or nucleus, in the fourth ventricle of the brain, just above the medulla oblongata. Their distribution and function is as follows:

Second Nerve (Optic Nerve). Supplies the retina. Function: Vision. The nucleus of this nerve is in the occipital lobe.

Third Nerve (Motor Oculi). Supplies all the extrinsic muscles of the eyeball, except the external rectus and the inferior oblique. Function: Rotation of the globe. Supplies the ciliary muscle. Function: Accommodation. Supplies the iris

muscles. Function: Contraction and expansion of the pupil. Supplies the levator palpebrae. Function: Raising the eyelid.

Fourth Nerve (Patheticus). Supplies the superior oblique muscle of the eyeball. Function: Rotation of the eyeball obliquely upward and outward.

Fifth Nerve (Sympathetic). Supplies the eyeball and lids. Function: Sensation of these parts. Also nutriment of the eye.

Sixth Nerve. Supplies the external rectus muscle. Function: Rotation of the eyeball outward.

Seventh Nerve (Nerve of Facial Expression). Supplies the orbicularis palpebrae muscle. Function: Closing of the eyelid.

The third nerve does not itself reach and supply the intrinsic muscles, but delivers its nerve-impulse through the ciliary and otic ganglia to the short ciliary fibres of the sympathetic, which supply these muscles.

BLOOD VESSELS.

The eye has three systems of blood vessels, viz., (1) The retinal vessels, (2) the uveal, or ciliary, vessels, and (3) the conjunctival vessels.

(1) The retinal blood supply is derived from the central retinal artery, which enters the eye through the optic foramen, along with the optic nerve, and divides into the retinal arteries, ending at the ora serrata. The retinal veins coalesce into the central retinal vein, which also passes out through the optic foramen.

This system of vessels forms a terminal loop, which does not anastomose with any other vessels of the eye; hence if anything happens to the central retinal arteries there is no compensation of circulation. Occasionally there occurs, as an anatomical anomally, an anastomosing artery communicating between the retinal and ciliary systems, known as a cilio-retinal artery.

(2) The uveal, or ciliary, system is by far the largest and most numerous of the three systems. Its posterior division is derived from the ophthalmic artery, which enters the eye near the posterior pole and divides into several branches. Most of these go at once to the choroid, and are termed the short pos-

terior ciliary arteries. Two of them, the long posterior ciliary arteries, run, one on the outer and one on the inner side, between the choroid and the sclera, as far forward as the ciliary muscle, where each divides into two branches; these run concentrically with the ciliary ring and unite with the arteries of the opposite side to form the major circle of the iris, from which arteries go to the iris. Shortly before they reach the iris, these anastomose to form the minor circle of the iris.

The anterior ciliary arteries are derived from the arteries of the four rectus muscles, and perforate the sclera near the corneal margin to help form the major circle of the iris.

The short posterior ciliary arteries, therefore, chiefly supply the choroid, the long posterior and the anterior the ciliary body and the iris.

The veins of the iris and of the ciliary body and those of the choroid are collected into the vasa vorticosa; some veins, however, from the ciliary muscles leave the eye as anterior ciliary veins, with which the canal of Schlemm anastomoses.

(3) The conjunctival system consists of posterior conjunctival vessels, communicating with the anterior ciliary vessels, which run to meet them, forming the marginal loops of the cornea.

EYELIDS.

Two folds of external skin project themselves over the eyeball, to cover and protect it, above and below. These are the eyelids. The boundaries of the upper lids are formed by the eyebrows, two lines of bushy hair; but the lower lids merge imperceptibly into the skin of the cheek. The space between the two lids, when open, is called the palpebral fissure; the angle where they meet, the canthus, internal and external, respectively.

The skin covering the eyelids is very thin. Beneath the skin are the muscles by which the lids are moved (orbicularis palpebrarum and levator palpebrae) and the cartilaginous substance which gives them shape (the tarsus). On the inner surface the lids are lined with reflective conjunctiva, under which are the Meibomian glands and sebaceous glands, both of which secrete lubricant for the lids. Along the margins of the lids are hair follicles from which the lashes grow.

The lids, brows and lashes, together, constitute what are known as the tutamina, i. e. agents of safety.

LACHRYMAL APPARATUS.

The lachrymal gland, which secretes the tears, consists of two parts, the superior, lying in the upper outer angle of the orbit, and the inferior, lying under the mucous membrane of the fornix. Both empty into the conjunctival sac by means of ducts.

The tears drain into the lachrymal sac, which opens from the lower eyelid, near the inner canthus, on a slight prominence called the puncta lachrymalis. Thence into the lachrymal canal, which runs through soft tissue to the superior maxillary bone, where it becomes continuous with the bony lachrymal duct, which opens into the inferior meatus of the nose.

Angle. There are several special angles met with in optics, principally made either by tangents to reflective and refractive surfaces, or by various axes of reflecting and refracting systems. The most common of them are defined below.

Angle Alpha. The angle made by the intersection of the visual axis and the principal axis at the nodal point of the eye. The longer the antero-posterior diameter of the eyeball, the smaller this angle appears to be, because the further the retina is from the point of intersection, the less is the arc subtending the angle. Hence, in myopia the angle alpha appears smaller than normal, giving an appearance of internal deviation, while in hyperopia exactly the opposite state of affairs exists. This constitutes what is known as apparent strabismus.

Critical Angle. The acute angle of incidence (see below) beyond which light does not pass from a dense into a rarer refracting medium, but is totally reflected from the surface. Beyond this point, of course, reflection is the most brilliant possible. The critical angle between water and air is 48° 35′; between glass and air 41° 48′.

Angle Gamma. The angle formed by the intersection of the principal axis of the eyeball with the visual angle at the centre of rotation of the eyeball. This angle has no particular working value in optometry.

Angle of False Projection. When light from an object is refracted by a prism, there is an apparent displacement of the

image toward the apex of the prism. (See **Prism.**) The angle formed by the visual axis, projected to the false image, with the incident ray is called the angle of false projection.

Angle Kappa. The angle between the line of fixation and the normal to the cornea which passes through the centre of the cornea.

Angle of Convergence. The angle made by the two visual axes with each other when the eyes are turned inward. It varies, of course, with the degree of convergence, being most obtuse at the point of greatest convergence.

Meter Angle. The angle made by each visual axis with the median perpendicular when the eyes are turned inward. It varies, of course, with the degree of convergence, and is exactly half the angle of convergence (see above). It is used more than the angle of convergence in calculating problems of convergence.

Prism Angle. The angle made by the two refracting sides of a prism at its apex.

Angle of Deviation. The angle made by a ray of light, after passing through a prism and being refracted by it, with the path of the incident ray, both being projected to meet each other.

Angle of Incidence. The angle made by a ray of light, as it strikes a reflecting or refracting surface, with the perpendicular to that surface.

Angle of Reflection. The angle made by a reflected ray of light with the perpendicular of the reflecting surface. In reflection the angle of incidence and the angle of reflection are always equal.

Angle of Refraction. The angle made by a ray of light, as it emerges from a refracting medium, with the perpendicular to the surface from which it emerges. This angle, of course, is by no means always equal to the angle of incidence, but varies with the index of refraction. In fact, the ratio between the sines of the angles of incidence and refraction measures the index of refraction.

Visual Angle. The angle formed at the nodal point of the eye between two lines drawn from the yellow spot to the extreme boundaries of the object viewed. It is the size of this

angle which is the principal factor in judging of the size of the object, and also its distance away. The further away an object is, the smaller visual angle it subtends. (This constitutes what is known as perspective.) The smallest visual angle which an object can subtend and be discerned is 1 minute; this is called the minimum visual angle.
(See ACUITY.)

Angulus. An angle. See **Angle.**

Anianthinopsy. Violet-blindness.

Aniridia. Absence of the iris.

Aniscoria. Inequality of the size of the two pupils.

Anisometropia. A difference in the refraction of the two eyes, so that one focuses neutral waves behind the retina (hyperopia) and the other in front of the retina (myopia). Usually it is congenital, in which case the person, as a rule, uses the hyperopic eye for distant vision and the myopic eye for near vision.

Annexa. A general term applied to parts which are adjacent and subservient to an organ. The annexa of the eye are the lids, lashes, eyebrows, etc.

Annulus Cilliaris. The ring-like boundary between the iris and the chorioid.

Anopsia. Disuse of the eye. The most common instance of anopsia is where the patient has diplopia, and in order to rid himself of the annoyance of "seeing double" learns to disregard the image in one of his eyes. This eventually results in an inability to see with the disused eye, known as amblyopia ex anopsia. There are, however, other causes for anopsia.

Anophthalmia. Absence of the eyes.

Anotropia. Turning of the eye upward. See **Strabismus.**

Antagonism of the Visual Field. When the images of the two visual fields are of such a nature that they cannot be fused, one or other of the visual fields will predominate to the exclusion of the other. It is impossible to say which will predominate.

Usually one predominates until some slight motion of the eye changes the situation, when the other will predominate. (See **Binocular Vision.**)

Anterior. Toward the front.

Anterior Chamber. The chamber of the eye lying in front of the crystalline lens, containing the aqueous humor.

Anterior Focal Point. The focal point of a lens lying in front of the entering surface.

Anterior Pole. The point where the anterior surface of a lens cuts the principal axis.

Anterior Staphyloma. Bulging of the anterior surface of the eye, i. e. of the cornea.

Anterior Synechia. Adhesion of the iris to the cornea.

Anticloudine. A preparation for preventing the condensation of steam or vapor on glass lenses.

Aperture. Technically this term is used in problems connected with a refracting lens system to denote the width of the angle made with the principal axis by rays of light from an object-point. Ordinarily, the nearer the object-point is to the lens the wider is the aperture. We can, however, vary the aperture in any given problem by limiting the number of divergent rays we deal with.

Apex. The point of meeting of two sides of a triangle. In optics, its chief application is to a prism. The apex angle of a prism is the angle made by the two sides, where they meet.

Aphakia. Absence of the crystalline lens, either congenital or following extraction.

Aphose. A subjective sensation of a dark spot in the line of vision.

Aplanatic. A term applied to reflectors, lenses, and combination of them, which are capable of transmitting light with neither spherical nor chromatic aberration. Usually accomplished by combining substances of different optical density and other qualities, which counteract each other's aberration.

Apochromatic. A term applied to an improved achromatic lens, which does away with the secondary spectrum in the ordinary achromatic lens, and which corrects spherical aberration for two colors instead of only one.

Apparent Strabismus. An appearance of squint in high hyperopia or myopia, due to the smallness or largeness of the angle alpha (q. v.).

Aprosexia. Lack of attention, due to ocular defects.

Aqueous Humor. The transparent, watery fluid which fills the space in the eye between the cornea and the crystalline lens. The iris floats in this fluid, dividing the space into the anterior and posterior chambers. It is really nothing but water with a few salts in solution; of albumin it contains only a faint trace.

It is generally agreed that the aqueous humor is secreted mostly by the ciliary body, a little being secreted by the iris. That which comes from the iris leaves the chamber easily by way of the ligamentum pectinatum; that which is derived from the ciliary body has no such direct outlet. Since a greater quantity is secreted by the ciliary than by the iris, the flow is forward, toward the ligamentum pectinatum, by which it escapes; perhaps this flow is continuous, perhaps periodic. Occlusion produces intra-ocular tension, as seen in glaucoma. The quantity of aqueous humor secreted was formerly greatly exaggerated, observers being misled by the fact that when the chamber is emptied by puncture the fluid regenerates itself and fills the chamber again in about six minutes. This fluid, however, is not the perfectly organized humor; it is rich in albumins, and contains the protective bodies (alexins) of the blood which defend against infection.

As a refracting medium the aqueous humor has an index of 1.336, which, being practically the same as that of the cornea, prevents it from being an active factor in refracting the light which enters it from the posterior surface of the cornea.

Arcus. An arc-shaped cloudy formation on the cornea or the crystalline lens.

Arcus Senilis Corneae. A cloudiness which appears in old age near the corneal margin, showing first as two arcs, on the

upper and lower margins respectively, which presumably coalesce to form a ring.

Arcus Senilis Lentis. A ring-like opacity found in old people near the equator of the lens. It does not interfere with vision, as it lies wholly behind the iris, and it shows no disposition to spread.

Arcus Juvenilis. Occasionally the above phenomena occur in young people, in which event they are called arcus juvenilis.

Arcus Tarseus. The two arterial arches from which the conjunctiva of the upper eyelid obtains its blood supply. They are known as the superior and inferior arches, respectively.

Argamblyopia. Another word for amblyopia ex anopsia.

Argyll Robertson Pupil. A condition in which the pupil does not contract when light is thrown upon the retina, but contracts under accommodation. It occurs in diseases of the central nervous system, such as locomotor ataxia, myelitis, etc. (See **Reflex.**)

Argyrol. An organic salt of silver, extensively used as a collyrium in inflammations of the eye. It is employed in solutions of 5% to 25% in distilled water, and is much safer and better than nitrate of silver.

Argyrosis. Black or grey discoloration of the skin or a mucous membrane, due to the continued use of silver salts, particularly nitrate of silver.

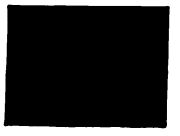
Arteries. All the arteries of the eye and the optic tract are derived from the internal carotid artery. This artery, so far as these organs are concerned, gives off three subsidiary arteries two of which, the chorioidal and the posterior communicating, go to the optic tract, and one, the ophthalmic, goes to the eyeball, dividing into the numerous branches which supply the globe. The arterial system, therefore, is as follows:

Chorioidal.	Optic tract.
Posterior Communicating.	Optic tract.
Central Retinal.	Retina.
Short Posterior Ciliary.	Chorioid.
Long Posterior Ciliary.	Chorioid and Ciliary Body.

Conjunctival.	Conjunctiva.
Frontal.	Supraorbital region.
Lacrymal.	Lacrymal gland.
	External rectus muscle.
	Superior Rectus Muscle.
	Upper eyelid.
Anterior Ciliary.	Conjunctiva.
	Ciliary Body.
Internal Maxillary.	
Infraorbital.	Inferior rectus muscle.
	Inferior oblique muscle.
	Lacrymal gland and sac.
	Lower eyelid.

The zygomatico-orbital artery, having its origin in the temporal artery, supplies the orbicularis palpebrarum muscle.

Artificial Eye. A glass eye, made to resemble the natural eye, to be inserted in the orbit to take the place of an eye which has been enucleated. These eyes are nowadays made with great art. They usually last about a year, after which they lose their smoothness and are apt to irritate the socket.



Artificial Eye.

As. An abbreviation for astigmatism.

Associated Movements. In physiology this term refers to muscular movements which, while they are not dependent upon each other, are instinctively performed simultaneously. A familiar and ludicrous example are the movements of the tongue with which a child often accompanies the act of writing. A more sensible one is the swinging of the arms when walking. No doubt the physiologic relation between accommodation and convergence is that of associated movements.

Asthenopia. This is a broad term used to designate a group of symptoms arising from any form of functional eye-strain, including that type of muscular and nervous exhaustion due to

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heterophoria. In a general way, these symptoms are the same, from whatever specific cause they arise, and in the last analysis they are essentially reflex in their character, dependent upon an excessive or unequal innervation, and mediated primarily through the ocular and fifth cranial nerves.

SYMPTOMS.

Asthenopia manifests itself in an inability to sustain a steady or prolonged use of the eyes, and by more or less pain and discomfort when this is attempted. The pain may be of any degree of severity, even to an agonizing neuralgia. At times there is no actual pain at all, but after a prolonged use of the eyes the vision becomes blurred and the patient is obliged to rest.

If, in spite of the inconvenience, the patient forces himself to continue his work, he will presently begin to develop positive signs of inflammation, such as photophobia, conjunctivitis, etc. Headache is a prominent symptom of asthenopia, and assumes various forms. Hyperopia usually gives brow headache, similar to that of nasal catarrh. Astigmatism, pain in the back of the neck, with tender spots upon the head.

The organs and functions most closely associated with the ocular nerves are those of digestion; hence the commonest systemic disturbances resulting from eye-strain are those of stomach and bowel disorders; lack of appetite, dyspepsia, nausea, vomiting, constipation, etc. Next to these come disturbances of the general nervous system, such as chorea, bed-wetting, insomnia, and even epilepsy. Dizziness is always a more or less noticeable accompaniment of eye-strain, because it is by the unconscious estimate we make of the amount of nerve energy expended in accommodation and convergence that we largely make our visual judgments; and when these faculties are unnaturally exercised dizziness results.

VARIETIES.

A common form of asthenopia is that which results from muscular imbalance, by reason of the unequal or excessive innervation performed by the patient in order to obtain single vision. This type is known as muscular asthenopia, indicating that its seat is in the extrinsic ocular muscles.

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A second form of asthenopia, which really also belongs in the muscular class, is that which arises from straining of the ciliary muscle in cases of hyperopia or hyperopic astigmatism. For the sake of distinction from that which depends upon the extrinsic muscles, however, this variety is usually termed accommodative asthenopia. It is by far the commonest form of the trouble, as hyperopia and hyperopic astigmia are the commonest errors of refraction. Furthermore, it is the type that gives most trouble to the refractionist, because it connotes a ciliary spasm.

A third and rarer type of asthenopia is that which comes from hyper-sensitiveness or fatigue of the retina, either due to close and continuous work in a bright light, or over glittering materials or to constitutional diseases. This is called retinal asthenopia.

REFLEX EFFECTS.

It is well known that the muscular activities of the body are under the control of the nervous system. It is further known that this great system of nerve fibres and centres crosses and recrosses, exchanging small connecting fibrils, like some vast telephone or telegraph system, with "crossed wires," so that all the centres and out-posts (peripheries) are intimately connected with each other. Not one is isolated or independent of another, and while a nerve current may be sent by a special centre along a special nerve path to a group of muscles to perform a special act, yet every nerve centre and every organ in the body shares to some extent in the nervous discharge.

In the furnishment of this motive control by the nerve centres under normal conditions there is an economic regulation of the amount of nerve energy furnished, in accordance with the amount of work to be done. Especially is this the case where very fine, delicate movements are to be made, requiring nicety of judgment. Usually, for such acts, two sets of muscles have to be employed, one set opposing the other, and the motive force supplied to each set is nicely balanced so as to give precisely the needed resultant effect. This is called co-ordination.

The functions of accommodation and convergence both belong to this class. Under normal conditions, precisely the same amount of nerve discharge is required for the extrinsic

muscles of each eye to hold the eyes balanced in proper convergence, and the same for each ciliary to maintain equally focussed images on the retinae. But suppose that the refraction of the two eyes is different; then, in order to satisfy the demand for clear vision, one ciliary must contract more than the other; an unnatural and unequal innervation must be performed. In other words, co-ordination becomes an unnatural and extraordinary effort.

Again, suppose that the conditions of convergence are abnormal. The exercise of accommodation, as we know, is a normal and powerful stimulus to convergence. Hence, when, as in hyperopia or myopia, the normal relation between the two functions is disturbed, the natural tendency of convergence is to follow suit, which it is prevented from doing only by an unnatural innervation of the muscles concerned.

In either of these abnormal conditions, then, the nervous effort required to balance the muscles to the desired resultant of function is unnatural and extraordinary. But, as already explained, the whole nervous organization of the body shares in the nervous discharge of any one function, and this is true to a special degree in the case of vision, which is so essential a factor in every act, emotion, or thought. Hence any unnatural and extraordinary exercise of the nervous mechanism of vision cannot but make itself very quickly felt in an unnatural and extraordinary nervous impression upon other organs and functions. Thus it is that many cases of digestive and nervous disease are caused by eye-strain, and may be cured by the proper fitting of glasses, which correct the refractive errors, render the eyes normal, and equalize innervation.

Astigmatism. The word literally means "without a point." It denotes a condition of the eye in which waves of light are not focussed at one point, as in the normal eye, but at two separate focal points. This is due to the fact that the curvature of one of the refracting surfaces of the eye—usually the cornea, but sometimes the crystalline lens—instead of being spherical, is paraboloid, i. e., made up of two different spherical curves intersecting each other at right angles; and each of these curvatures has its own set of focal points, those of the most convex curvature lying more anterior than those of the least

convex. Under such conditions, it is evident, a clear retinal image cannot be obtained of any object, since the two sets of foci cannot be upon the retina at the same time. Hence astigmatism is incompatible with clear vision.

The cause of astigmatism is a much mooted question. The normal eye is slightly astigmatic, being a trifle more convex in the vertical meridian than in the horizontal; not enough,

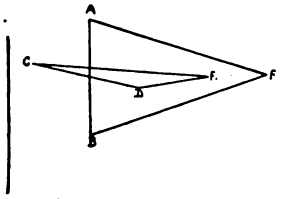


Diagram of Astigmatism, the Vertical Meridian focussing at F, and the horizontal meridian at F^1, the relative positions of F and F^1 with regard to the retinal plane determine the kind of Astigmatism.

however, to interfere noticeably with clear vision. Some attribute this to pressure of the eyelids; others to the action of the extrinsic muscles. If these theories be true, then cases of abnormal astigmatism can hardly be regarded as exaggerations of this normal irregularity in curvature, for while they might account for corneal astigmatisms in which the greatest convexity is vertical, they would not explain the opposite type of corneal astigmatism, or any kind of lenticular astigmatism. The strong probability is that all cases are congenital, and depend upon some defect in biological development.

VARIETIES.

As stated, the great majority of astigmatisms are corneal, i. e., due to paraboloid curvature of the surface of the cornea; some five to ten per cent are lenticular, i. e., due to paraboloid curvature of the crystalline lens.

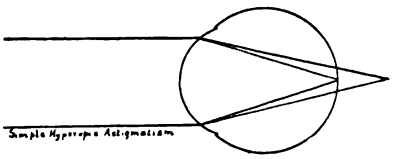
Irregular Astigmatism. Occasionally cases of astigmatism are met with in which the two intersecting curves are not at right angles to each other, but intersect obliquely; and still others in which there are several different curvatures, lying at various angles. Such cases are known as Irregular Astigmatism, and are usually due either to injury (corneal ulcers, wounds, etc.) or to operations on the eye (cataract extractions, iridectomies, etc.). The detection and management of these cases will be dealt with in a separate fashion.

Regular Astigmatism. By far the vast majority of cases of astigmatism are regular, i. e., they exhibit but two different curvatures, which intersect each other at right angles. The two meridians of greatest and least curvature, respectively, are known as the principal or chief meridians. Only in these two meridians is the curvature spherical; in intermediate meridians there are differing grades of paraboloid curvature.

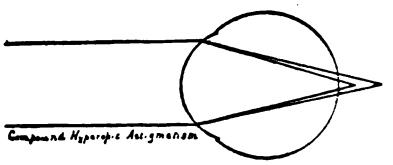
When the two chief meridians are vertical and horizontal, respectively, the condition is said to be a right astigmatism; when they are at other angles, it is termed an oblique astigmatism. Further, when the meridians of greatest and least curvature follow the order exhibited in the normal eye, namely, the greatest curvature vertical and the least curvature horizontal, we say that the astigmatism is "with the rule"; when this order is reversed, we say it is "against the rule."

From an optical standpoint, there is, strictly speaking, but one kind of astigmatism, the essential element of the condition being that one principal posterior focus lies in a more anterior plane than the other, or (what is the same thing) one lies in a more posterior plane than the other. Whatever other classification we give to cases of astigmatism really pertains to, and depends upon, co-existing conditions of emmetropia, hyperopia or myopia. For clinical convenience, however, we classify astigmatism according to the relative positions of the two posterior principal foci with reference to the retinal plane:

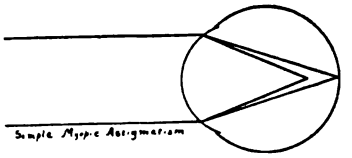
1. Simple Hyperopic Astigmatism, where one posterior principal focus lies in the retinal plane and the other posterior to it.



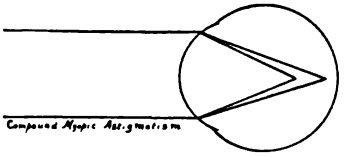
2. Compound Hyperopic Astigmatism, where both posterior principal points lie posterior to the retinal plane.



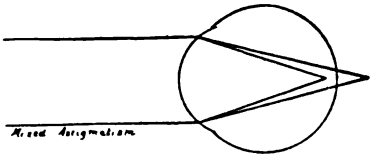
3. Simple Myopic Astigmatism, where one posterior principal focus lies at the retinal plane and the other anterior to it.



4. Compound Myopic Astigmatism, where both posterior principal foci lie anterior to the retinal plane.



5. Mixed Astigmatism, where one posterior principal focus lies anterior, and the other posterior, to the retinal plane.



Next to hyperopia, (with which it is frequently associated), astigmatism is the most frequently encountered of refractive errors. And, as hyperopia is the most frequent of the spherical errors, so hyperopic astigmatism is the most frequently met type of astigmatism.

CYLINDERS IN ASTIGMATISM.

Fortunately, astigmatism, once it is detected and measured, is very easily and accurately corrected, by means of a lens made from a segment of a cylinder. (See **Lens.**) And as cylindrical lenses also play the major role in subjective tests for astigmatism, it will be well to point out in this place their application to this refractive error.

A cylindrical lens has been elsewhere described as being, optically, the split half of a sphere. By placing it before the eye, therefore, we can add to (with a convex cylinder) or subtract from (with a concave one) the curvature of the eye in one meridian—the meridian at right angles to the axis of the cylinder—without changing the power of the opposite meridian. If,

therefore, a cylinder of the proper degree of curvature, plus or minus, be placed before the eye with its axis at right angles to the chief meridian which it is designed to influence, it will move the principal focal point of that meridian backward or forward, as the case may be, until it is coincident with the focal point of the other meridian. Both chief meridians now focussing alike, the refraction of the eye is that of a sphere; astigmatism has ceased to exist. If the amalgamated focal point is not in the retinal plane, a spherical lens of the proper curvature and power will put it there.

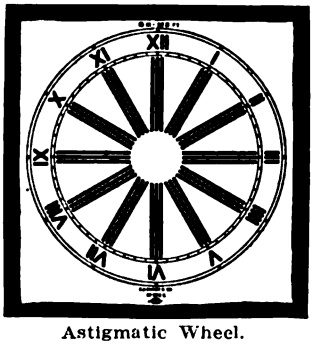
Plainly, then, the correcting cylinder in astigmatism must always be equal in dioptrism to the difference between the two chief meridians. Whether it be plus or minus is immaterial, for it matters nothing which of the two focal points is moved so as to coincide with the other. The axis of the cylinder must be across the meridian it is intended to influence, as the power of a cylinder is at right angles to its axis.

DETERMINATION OF ASTIGMATISM.

Subjective determination of astigmatism depends upon the fact that it is impossible to see clearly, at the same time, in both meridians of the visual field corresponding to the principal meridians of curvature. All subjective tests are designed (a) to narrow these contrasting meridians down, and to emphasize their contrast, and (b) to find the lens power which will focus them both on the retina simultaneously, and give clear spherical vision. Since astigmatism is a static condition, depending upon the curvature of the cornea or lens, it is tested for with the eye in a static condition, i. e., at infinity.

The simplest test is that afforded by the astigmatic wheel chart, consisting of a radiating series of black lines, radii of a circle, corresponding to the various angular degrees. It is evident that two of these lines, at right angles to each other, will represent the patient's two chief meridians of refraction, and he will see one of these lines more clearly than all the rest and the opposite one least clearly of all. If we now find a cylinder which, properly placed, will make all the lines appear equally black, we shall have made the two chief meridians equal, and corrected the astigmatism.

There are several possible sources of error in this rather crude method; for one thing, the difference between the two chief meridianal lines is often hard to distinguish when all the intermediate lines are in full view; and, besides, if the patient happen to have a mixed astigmatism, in which the two chief meridians are about equally hyperopic and myopic, respectively, there will be no noticeable difference in the two meridianal lines.



Astigmatic Wheel.

To make the test more delicate and dependable, it is better to "fog," i. e., put a strong plus lens before the tested eye which blots the chart out altogether, and then, by gradually adding minus power, gradually move the principal focal points of the two chief meridians back until one of them (that of least curvature) falls on the retina. At once one of the lines will come into vision, and no others. We then find a minus cylinder which, with its axis across the black line, puts the other focal point back at the same plane, so that all the lines are seen equally. This cylinder is the measure and correction of the astigmatism. If any spherical error now remain, its correction can be proceeded with.

THE STENOPAIC SLIT.

Another subjective test is by means of the stenopaic slit—an opaque disk with a single straight slit in it through which the light will enter the eye along one meridian only. If we revolve this slit before the eye, in the graduated frame, directing the patient to look at the letter chart, we shall find an angle at which the slit will give the best vision, and one at which it will give the worst. These represent the two chief

meridians. All we now have to do is to find a spherical lens, plus or minus, which will make vision normal through the slit at each of these angles, and the difference of dioptrism between these two lenses (calculated algebraically) will be the measure of the astigmatism. The balance of the correcting lens power

Stenopaic Slit.

will represent the spherical correction to be combined with the cylinder.

Thus, if we find that with the slit at 90 deg. we get the best vision, but it requires a plus 2 D. to make it 20/20; and at 180 deg. we get the worst vision, requiring plus 3 D. to make it 20/20; the patient's astigmatism is the difference between plus 2 D. and plus 3 D., i. e., plus 1 D. A plus 1 D. cylinder with its axis at 90 deg. (i. e., across the most hyperopic meridian) will correct the astigmatism, making both meridians alike. The additional plus 2 D. sphere will correct the remaining hyperopia. This example, by-the-way, is a case of compound hyperopic astigmatism, with the rule.

Objective methods of finding and estimating astigmatism are retinoscopy and ophthalmometry. Detailed accounts of the application of these two instruments to astigmatism will be found under **Retinoscopy** and **Ophthalmometry** respectively.

As previously stated, a small percentage of astigmatisms are due to non-spherical curvature of the crystalline lens. There is no objective method of determining lenticular astigmatism. Hence, in measuring astigmatism objective methods should always be checked up by subjective tests.

Astigmometer. The same as an Ophthalmometer, q. v.

Asymmetry. A lack of similarity, in size, position, etc., between the two things that are being compared—e. g., of the sides of the face, the eyes, etc. No human being has symmetry of any part of the two sides of the body; but unless it is noticeable we do not call it asymmetry.

Attollens. Applied to a muscle which raises a part. Attollens oculi is the superior rectus muscle of the eye.

Aura. A subjective sensation which heralds the approach of a loss of consciousness, as in epilepsy, fainting, etc. Often this aura consists in a visual sensation, such as a scintillating scotoma, or a flash of light, or an illusionary image.

Autophthalmoscopy. The art of viewing one's own eye through the ophthalmoscope.

Axanthopsia. Yellow-blindness.

Axis. An axis is an imaginary straight line drawn through a body, or a system, around which the body or system groups itself symmetrically.

The axis of a sphere coincides with its diameter, and may be drawn through the center in any direction. However, for working purposes, when once an axis has been drawn through a sphere, it is regarded as the principal axis, and all other lines drawn through its center are regarded as secondary axes. In like manner, in a spherical lens, which is a segment of a sphere, the principal axis passes straight through the center of its segmental curvature perpendicular to the surface; all other lines passing through perpendicularly to its surface are secondary axes.

The principal focal point of a spherical refracting or reflecting system is always situated on its principal axis.

The principal axis of the eye, which is a spherical refracting system, passes through the center of the cornea, and the geometric center of the eyeball, to the geometric center of the retina. On this axis, at the plane of the retina, is the principal focal point of a normal eye. Other lines which pass through the cornea perpendicularly to its surface are secondary axes.

A cylinder has two axial systems. The axis which passes through the center of the circular aspect parallel to the plane

aspect of the curved side is called the cylinder axis. But as its refracting power lies in its curvature, it is ascribed a set of axes perpendicular to this curvature, passing through its circular center, similar to those of a sphere. The principal axis passes perpendicularly through the center of its curvature; all other axes passing through it perpendicularly to its curvature are secondary axes. So with cylindrical lenses, which are segments of cylinders.

The visual axis is an imaginary line drawn straight from the yellow spot (moacula lutea) through the nodal point (q. v.) to the object looked at. It will be seen that this axis, which is the line of attentive vision, does not coincide with the principal axis of the eye, the yellow spot being a little to the temporal side of the optical center of the retina.

The eyeball has several axes of rotation, imaginary straight lines around which it rotates, according to the muscle or muscles in play and the direction of their action. All of these axes are oblique, owing to the combined action of the oblique muscles with every pair of recti.

Axonometer. An instrument for rapidly determining the axis of a cylindrical lens; also for determining the axes of the chief meridians in an astigmatic eye.

Most axonometers of the first kind are based upon the fact that when a straight line is viewed through a cylinder other than parallel or perpendicular to its axis, it apparently loses its continuity and is broken into two lines separated laterally from each other. (See **Lens.**)

Bacillar Layer. The rods and cones of the retina.

Band, Astigmatic. An apparent band of light which is seen to lie across the pupil of an astigmatic eye, under retinoscopy, when one of the chief meridians is neutralized. See **Retinoscopy.**

Bands, Spectrum. Spectra of gaseous bodies, consisting of bright bands of color.

Base Curve. The standard curve which opticians use in grinding the back surface of toric lenses. The other surface is then ground so that, in combination with the base curve, it gives the

desired compound optical effect. Originally there were three such standard base curves, 3 D., 6 D., and 9 D., but nowadays opticians vary them to suit their facilities. (See **Lens.**)

Baum's Ophthalmoscope. An electrical ophthalmoscope invented by the German ophthalmologist, Baum, in which the light is refracted through a prism instead of being reflected by a mirror.

Bi-Astigmatism. A condition of the eye in which both corneal and lenticular astigmatism co-exist.

Bi-Axial. A term applied to those crystals which perform double refraction. See **Diffraction.**

Bi-Concave. Concave on both sides. (See **Lens.**)

Bi-Convex. Convex on both sides. (See **Lens.**)

Bifocal. Literally, having two foci. The term is specifically applied to lenses made up of two parts, each having a different refracting power, and therefore a different principal focal point; one part, as a rule, being intended for distant vision and the other for reading and close work. They are specially applicable in presbyopia (q. v.).

Bifocals were the original device of Benjamin Franklin, and there have been innumerable different forms devised and used from Franklin's time to the present day. In these days, however, there are practically but three forms in common use:

(1) Cement bifocals, in which the larger refracting power is attained by cementing a wafer of greater curvature onto the front or back of the lens. The wafer is usually either circular or oval in shape, and placed flush with the lower edge of the lens, so that the visual axis may pass through it when the eyes are converged and lowered for reading.

(2) Onepiece bifocals, where the two different curvatures are ground on the same piece of glass. In some types the near vision portion practically merges into the distant vision portion or main lens; in others the near vision portion or segment is depressed, thus forming a slight abrupt ridge or shoulder separating the two portions of the lens.

(3) Fused bifocals, in which the higher-power part is furnished by a fused insert of a denser quality of glass. Usually flint glass is fused into crown glass. The different melting

point of the two glasses permits this to be done; the greater optical density of the flint glass allows a higher refracting power to be obtained with proportionately less increase of curvature; and the line of junction between the two parts is practically invisible. These lenses are sometimes called "Invisible" Bifocals.

Binocular. The word is applied to anything that relates to the simultaneous use of both eyes in the act of vision. In regard to the eyes themselves, it signifies any function in which both eyes partake together, as binocular accommodation, binocular squint, etc. In regard to instruments, it signifies that the instrument is to be used by both eyes together, as binocular telescope, etc.

All functions of the eye are performed more vigorously in binocular than in monocular vision.

Binocular Vision. The single eye surveys a visual field which has a range of approximately 180 degrees horizontally and 130 degrees vertically. Inner portions of these two visual fields overlap, when both eyes are used together, forming a cone, with the nose as a vertex, in which both eyes see simultaneously and coincidently. This is the binocular visual field.

CORRESPONDING AND DISPARATE POINTS OF THE RETINA.

In order to obtain a single image of an object in the binocular visual field, if the object is pictured on a certain position on one retina it must be pictured on a certain definite and symmetrical position on the other retina. Portions of the two retinae which work together in this way are known as corresponding, or identical, points; portions which have not this coincidence are called disparate points. From the fact that we see objects singly upon which we fix, it is apparent that the two yellow spots are corresponding retinal points.

It is evident that as long as the head is held in one position the portion of space representing the binocular visual field remains the same; and that as the head and eyes are moved, the size and position and contour of this field change. Within the binocular field—and only within that field—there are certain points in space whose image-points will fall upon cor-

responding points of the two retinae, and be seen singly. The totality of these points is termed the horopter.

It is possible to determine, mathematically, for every position of the eyes, just what points in space will fall upon corresponding points of the retinae; that is to say, the extent and contour of the horopter. The horopter is a curve of the third degree. Three points through which it must pass are predetermined; they are the point of fixation and the nodal points of the two eyes. The latter points, and adjacent parts, are, of course, not pictured on the retina at all; this portion of the horopter is a purely mathematical quantity.

When the visual axes are parallel and symmetrical in relation to the median line, the fixation point is at infinity. If the middle cross-sections of the visual field are horizontal, the transversal planes which cut the retina in corresponding lines are coincident, and the entire binocular visual space is the horizontal horopter. If the cross-sections make an angle with each other, the transversal planes intersect at the median line, and this plane is the horizontal horopter. If the middle longitudinal sections of the field are vertical, the corresponding longitudinal planes intersect at infinity, and this is the vertical horopter. The point-horopter is the intersection of these two line-horopters.

When the visual axes are symmetrical, but not parallel, the fixation point is in the median line at a finite distance. The visual plane is the horizontal horopter. The vertical horopter is a cylinder perpendicular to the visual plane whose section by the plane is a circle passing through the point of fixation and the nodal points of the eyes (Muller's circle).

When the point of fixation is in the horizontal plane and the visual axes are symmetrical, the vertical horopter is a hyperboloid whose section with the median plane is Muller's circle. The horizontal horopter consists of the visual plane and a plane perpendicular to it passing through the intersection of Muller's circle with the median plane and through one end of the diameter of this circle which goes through the point of fixation. The point-horopter is Muller's circle and a straight line inclined to the visual plane which passes through the intersection point just described.

STEREOSCOPIC VISION.

Visual sensations are referred by projection to space of three dimensions, namely, length, breadth and depth. Perceptions of length and breadth are properties of monocular vision, and pertain to any and all portions of the visual field. Perception of depth, which is less perfectly developed, is possible only with binocular vision, therefore pertaining only to the binocular visual field, and is an optical function of the horopter.

No doubt much of our idea of depth arises from elements of experience, which, of course, is not a direct sensation, but an inference from other sensations. The comparison of the apparent size of various objects, for instance, enables us to form a judgment as to their respective distances. Simple geometrical forms with which we are very familiar produce an impression of solidity. The distribution of light and shade in the field of view is another such factor—not alone the shadows cast by objects themselves, but the degrees of illumination according as they are turned toward or away from the source of light. And finally, so-called aerial perspective is an important element, i. e., dimmed or veiled appearance of objects, or their parts, in proportion to the depth of atmosphere through which we view them.

Aside from these experiential factors, however, the eyes possess the faculty of perceiving depth as a direct sensation, which, as stated, pertains wholly to binocular vision. The muscle sense, as exercised in accommodation and convergence, is generally accepted as forming one of the component elements of this sensation. It is questionable, however, whether a judgment derived from the muscle sense can properly be regarded as part of an immediate sensation; and, besides, it plays a very small and unimportant part in depth perception, being necessarily restricted to the relatively small range of accommodation and convergence. The fact that we perceive depth in an object under sudden and momentary illumination; the further fact that facsimiles make equal impressions of solidity; and the still further fact that we are able to perceive solidarity far beyond the range of accommodation and convergence; all point to the insignificance of this element.

By far the most important factor in the sensation of depth is the difference in the images made by a solid object on the two retinae, respectively, and the difference in the relations of the horopter with the disparate object-points, due to the lateral separation of the two eyes by the interpupillary distance; that is to say, to the parallax of the two eyes. This perception of depth is known as stereoscopic vision. Stated mathematically, the stereoscopic parallax depends upon the distance between a point of the object and the vertical plane through the nodal points of the eye, and is inversely proportional to this distance. This difference arises in the moving of images in the direction of the line connecting the eyes: hence the use of the word "vertical" in the definition just given. It is impossible to perceive the difference in depth of a set of telegraph wires strung horizontally; but if the same group of wires are strung vertically, the difference of depth is easily recognized.

Stereoscopic vision is both direct and indirect. The direct exercise of the sense depends upon comparison of disparate points in the visual field with the fixation point; the indirect, upon comparison with one disparate point with another. Indirect stereoscopic vision is exceedingly important in daily experience, as it serves to protect us against danger from approaching objects of danger outside the range of the horopter.

The differences in depth which are stereoscopically perceptible vary directly with the square of the mean distance of the points. Helmholz found that a difference of 1 minute of arc is sufficient to be perceived. (It will be observed that this corresponds to the minimum visual angle.) The pupillary width in an average individual is 68 mm. Therefore, according to the formula,

$$\frac{68}{\text{sine } 1'} = 240 \text{ meters}$$

240 meters is the greatest distance for stereoscopic vision, and is known as the stereoscopic radius.

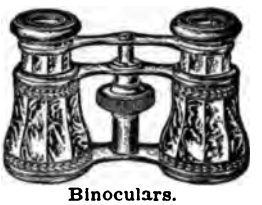
A 1 minute angle corresponds to .10 mm. in lengths. Therefore, pictures which differ .10 mm. manifest the difference if looked at stereoscopically. This fact is utilized for the detection of counterfeit bank notes and bills.

There are two ways of increasing the limit of stereoscopic vision, viz., (1) By increasing the keenness and range of vision, as in the case of the telescope and microscope, and (2) By increasing the inter-pupillary distance, by means of reflecting mirrors. All instruments designed for this purpose, and known as stereoscopes, are based upon these principles. (See **Stereoscope.**)

STRUGGLE OF THE VISUAL FIELDS.

When the two visual fields are represented by images wholly dissimilar to each other, it is impossible to fuse them, and one or other of the two fields predominates over the other; usually they take the predominance alternately. This condition, which in its extreme form, is known as the antagonism of the visual fields, obtains to a more or less degree in all binocular vision, constituting what is known as the struggle, or rivalry, of the visual fields.

Binoculars. A telescope with two barrels or lens systems, one for each eye; sometimes called "field glasses," but the term is applied by the optical trade generally to field glasses in which reflecting prisms are employed.



Binoculars.

Bi-Orbital. Relating to both orbits.

Blenorrhea. A profuse flow of pus from the eye. Technically the word is generally used to denote gonorrheal conjunctivitis.

Blepharism. A tendency to winking. May be the result of eye-strain, due to errors of refraction.

Blepharitis. Inflammation of the eyelids. Often the result of eye-strain, due to refractive errors.

Blepharospasm. Twitching of the eyelids, often due to eyestrain from uncorrected errors of refraction.

Blepharoplegia. Paralysis of the eyelids.

Blepharoptosis. Dropping of the eyelid.

Blepharostat. An instrument for holding the eyelids apart.

Blepharostenosis. Abnormal narrowing of the palpebral slit.

Blepharosynechia. Adhesion of the eyelids to each other.

Blepharotomy. A cutting operation on the eyelids.

Blindness. The word blindness is used to describe, in general, an inability to see, from whatever cause. Blindness may be partial or complete, relative (amblyopia) or absolute (amaurosis). Special forms of blindness are:

Color Blindness. Inability to distinguish all or some of the colors. (See **Color Blindness.**)

Day Blindness. A condition in which the patient sees badly in the day-time, better in the evening.

Letter Blindness. Inability to recognize letters either all the letters of the alphabet, or certain of them. It is a form of mind-blindness.

Night Blindness. A condition in which the patient sees poorly at night, better in the daylight.

Number Blindness. Inability to recognize numerals, all or certain of them. It is a form of mind-blindness.

Mind Blindness. Inability to give association or meaning to what one sees. Due to the disease of the great association areas of the brain.

Object Blindness. Same as mind-blindness.

Snow Blindness. Blindness from retinal exhaustion, due to exposure to the glare of light on snow.

Unilateral Blindness. Blindness of one eye only.

Word Blindness. Inability to recognize words, all of them or certain words. It is a form of mind-blindness.

Blind Spot. The circular spot on the retina formed by the entrance of the optic nerve. At this spot the retina is insensible to light stimulation; and light waves or images that fall on this area are not perceived. Advantage is taken of this fact to focus light on the blind spot when examining the interior of the eye with the ophthalmoscope.

(See **Optic Disc.**)

Blood Pressure. The word "pressure" is hardly the correct term to apply to the phenomenon which it is here intended to define. Tension would be a better word. Pressure is a one-sided exercise of power, which may be directed in any degree against a yielding body, offering no resistance, without the production of any tension at all. On the other hand, half the same amount of pressure, divided equally between two bodies and exerted against each other, will develop a large degree of tension. In fact, the tension thus developed is a physical and a mathematical product of the two opposing pressures; regarding one of them as representing force, and the other resistance, then

$$p = fr$$

where p stands for tension, f for force, and r for resistance. Thus, in exemplification of the statement made above, if we consider a force of 20 lbs. acting against a body whose resistance is 0, then the tension developed is equal to $20 \times 0 = 0$. If, on the other hand, a force of 10 lbs. be directed against a body offering 10 lb. resistance, then the tension developed will be $10 \times 10 = 100$ lbs.

However, as the term Blood Pressure has become general, we shall adhere to it, with the understanding that it is used in the sense of inter-objective tension. In this sense, Blood Pressure is the product of the force of the contraction of the heart muscle and the resistance of the blood vessels, operating upon and manifested through the fluid blood. For a thorough understanding of the subject, of course, it is necessary to have a comprehensive knowledge of the whole anatomy and physiology, not only of the circulatory system, but also of the entire body, since there is no part or function but plays a part in both the production and the consequences of blood pressure. We will, however, content ourselves with giving here a brief summary of the subject, with special reference to its mechanics and its clinical aspects.

MECHANICS OF BLOOD PRESSURE.

The blood, as everyone understands, lies within a closed system of vessels, in which it is kept moving round and round by means of a pump, in much the same way as the water in a hot-water heating system. It is true that this system of blood vessels is not absolutely water-tight; that its walls are perme-

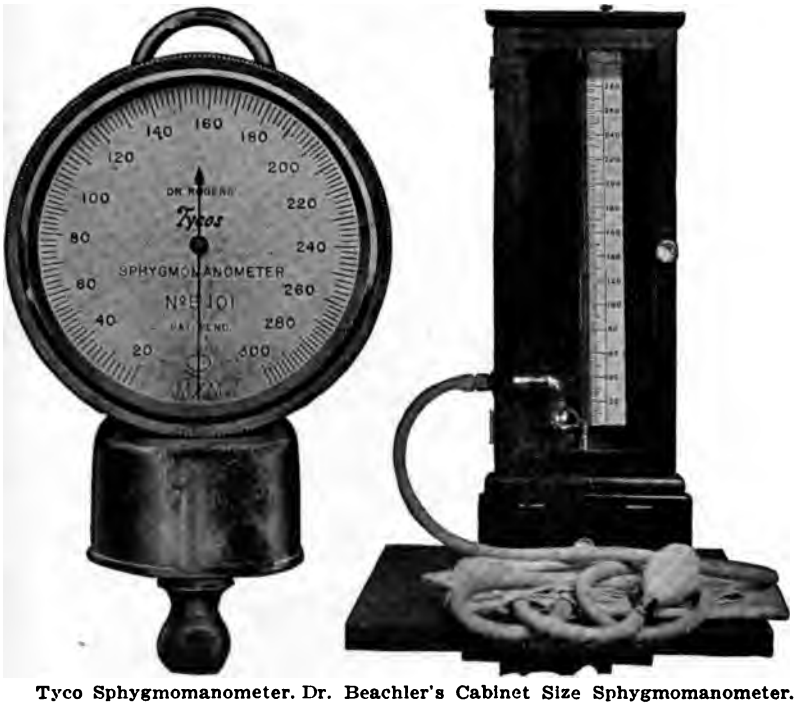
able, so that some of the fluid and a great deal of the gaseous content of the fluid, is continually passing in and out of the vessels; but, as the outgoing and incoming balance is maintained virtually constant, it may be regarded, so far as its mechanics are concerned, as a water-tight system.

The pump, in this case, is the heart, a large, powerful, hollow muscle, filled with blood, whose vigorous contraction throws a large volume of blood into the vessels, and forces the blood stream along them, and whose relaxation causing a dilatation of the hollow chamber, and forming a vacuum, draws blood into itself, by suction, ready for the next contraction. These contractions and dilatations, technically known as the systole and diastole of the heart, respectively, alternate with each other rhythmically, with a frequency of from 60 to 80 cycles per minute. As a matter of fact, the heart is a double organ, having two separate chambers, pumping and exhausting two separate systems of vessels. One, the shorter of the two, carries vitiated (venous) blood to the lungs and brings it back to the heart aerated, and is operated by the right side of the heart; the other, the longer system, carries aerated (arterial) blood through the body at large, and is operated by the left side of the heart. It is of the latter system that we shall speak here, although what is true of the one holds substantially good for the other.

The lay-out and character of the vessels through which the blood is forced form a most important part of the mechanism of blood pressure. The heart empties itself into one large artery (the aorta), which divides into two smaller arteries, whose total wall-area, however, is greater than that of the aorta; these two divide similarly into four; the four into eight; and so on, until all rather abruptly subdivide into thousands of tiny capillaries, whose total wall-area is some 800 times that of the aorta. On the other side of this capillary system the vessels just as abruptly recombine into an even number of small vessels, called veins, which then successively reunite, in a progression the reverse of the subdivision of the arteries, i. e. each time into half the number of vessels with a less total area, until at last two large veins pour the blood back

into the right chamber of the heart. These veins are called the superior and inferior venae cavae.

The arteries are furnished with elastic tissue which gives them elastic properties; i. e. they are distensible under force, but their elastic recoil tends to restore them to their original size. They are also furnished with circular muscles, forming part of their walls, (vaso-motor muscles), by whose contraction and relaxation the vessels can be contracted and dilated,



Tyco Sphygmomanometer. Dr. Beachler's Cabinet Size Sphygmomanometer.

respectively. The larger arteries are principally rich in elastic tissue; in the smaller arteries the muscular element predominates. The capillaries are neither elastic nor muscular. The veins are both, to a very slight degree, but as compared with the arteries we may regard them as almost inelastic and non-muscular.

The force of the heart-beat expends itself in maintaining the pressure in the arteries; it is lost by the time the blood enters the capillaries. When the blood emerges from the capillaries

into the veins, some slight impetus is furnished it in the suction referred to above, due to the vacuum made by the dilatation of the heart chamber in diastole; but chiefly the blood is kept moving by the difference of pressure in the arteries and in the veins, and by means of the valves, all closing backward, with which the heart and the veins are supplied.

We have, then as factors in the resistance offered by the vessels to the flow of blood, the following:

(1) Friction between the blood-stream and the vessel walls,
(2) The elastic recoil of the artery walls,
(3) The contraction of the vaso-motor muscles,

The net resultant of the product of these factors on the one hand, and the force of the heart beat on the other hand, constitutes the blood pressure. To which may be added, as a variant factor, gravity, or the weight of the column of blood above the point where the measurement is made, depending upon posture, etc.

Naturally, the blood pressure is not the same at various points in the system. Leaving out of consideration, for the moment, the muscular element, it is evident that the farther away from the heart we get, the less becomes the force of the heart-beat and the greater becomes the resistance—especially that offered by friction, since the total wall-area is progressively increasing along the arterial system. The blood pressure is greatest in the aorta, for there the force of the heart is at its maximum and the average of resistance is pretty high, and the product of the two is greater than at any other point. In the capillaries it is exceedingly low, for there the force of the heart is lost, and the resistance is very high. In the veins it rises again somewhat, for the vacuum suction increases the force a little and resistance is diminished. At the venae cavae, however, where the veins empty into the heart, there is neither force nor resistance, hence pressure at this point is zero.

All of this, however, is reckoning without the vaso-motors, which play a larger part in variations of blood pressure than any other single factor. These muscles are under the nerve control of the sympathetics. Normally, their office is to equalize the pressure as between two or more areas, so as to maintain a general average of pressure throughout the body. Thus,

during digestion, the splanchnic vessels are dilated and filled with blood at the expense of the vessels of the skin and muscles. The latter vessels being partially emptied, the pressure in them would fall; but the vaso-motors automatically contract, lessening their diameter, and maintaining normal pressure. In neurotic people, and in certain nervous diseases, the vaso-motors behave very erratically, causing all sorts of pressure disturbances—of which more later.

SYSTOLIC AND DIASTOLIC PRESSURE.

As already explained, the active cause of the pressure in the arteries is the contraction of the heart muscle, forcing the blood into and along the arteries against the resistance of the vessels. Naturally, this pressure varies at different points of time in the heart cycle. It is highest at the moment of maximal contraction of the heart, i. e. during systole. During diastole, when the muscle is resting and the heart dilating, it falls, its lowest point being reached at the end of the heart's resting period immediately preceding another contraction. During this period the pressure relation between heart and vessels almost reaches stable equilibrium; it never quite reaches this state, because the next heart-beat intervenes too quickly; but for all practical purposes the pressure condition during diastole may be regarded as static.

The maximal degree of pressure attained during systole is termed the systolic or dynamic pressure; the lowest degree during diastole, the diastolic or static pressure; the difference between the two necessarily represents the added pressure due to the contraction of the heart, and is known as the pulse pressure.

METHODS OF MEASURING BLOOD PRESSURE.

The first crude method of demonstrating and measuring blood pressure, (employed only on lower animals), was to thrust into the vessel a cannula attached to a graduated glass tube, and note the height to which the blood rose in the tube during systols and diastole. Modern methods and instruments depend upon the principle that if we compress an artery until its wall collapses, the pressure can then be diverted to, and taken up by, the instrument with which the compression is

made, which can be constructed so as to register it in some unit of measurement.

The instrument thus used is called a sphygmomanometer. There are several makes on the market, but all are essentially upon the same principle. The principal difference is in the method of registering the pressure, of which there are two general types. In one form of instrument the pressure is measured by the height of a column of mercury—this is, perhaps, the most accurate, and is the form generally used in laboratory work, where great precision is important. The other type registers the pressure through a coil spring, which revolves an index pointer on a graduated dial; this type is accurate enough for clinical purposes, and much more portable and convenient.

The compression is usually made by wrapping around the arm a large silk cuff, which is an air-tight pneumatic sac, and pumping air into it until the pulsations on the distal side of the cuff completely disappear. A tube from this sac leads to the registering device, and the air-pressure in the sac (which is the equivalent of the blood-pressure it collapses) is recorded. With some instruments, instead of the cuff, a small piece of hard substance (rubber) is strapped down on the arm, over the artery, this compressor communicating with an air-chamber or direct with the mercury. We shall confine ourselves to the former type of sphygmomanometer in describing the technique of the procedure.

TECHNIQUE.

Blood pressure—by which is meant arterial pressure, the only phase that concerns us—is practically always measured in the brachial artery of the left arm, because of its convenience. In general, the patient should be lying down, although it is sometimes desirable to make the test both standing and lying. In any case, successive tests should be made with conditions the same.

A sphygmomanometer of the type we are considering has a compression cuff, a piston or rubber ball for inflating it, a lever valve for deflation, and a dial, with an index needle, graduated into equivalents of millimeters of mercury.

Wrap the cuff evenly and tightly around the upper arm, the first lap of silk being placed over the inner aspect of the arm,

and tuck the final lap between the cuff and the arm. Place the fingers of one hand on the radial artery at the wrist, and with the other inflate the cuff until all pulsation at the wrist disappears and there is no movement of the index pointer on the dial, indicating that the arterial pressure has collapsed and there is a good margin of air pressure over.

Two methods of procedure are now open, the palpation method and the auscultation method.

Palpation Method. With the fingers still on the radial artery, the air is gradually let out of the cuff by means of the valve, meanwhile watching the fall of the needle on the dial. As it falls it begins to vibrate; the first vibrations, however, are due to the shaking of the cuff by the pulsations above it, and have no significance. In fact, the vibrations need not be regarded at all at this time. Presently the pulse will be just faintly felt at the wrist. Naturally, it first comes through at the point of maximal pressure, i. e. systolic pressure. The reading on the dial at this point, then, represents systolic pressure.

Continue to let the air slowly out of the cuff, carefully watching the dial. As the full pulse begins to come through, the needle will be seen rather abruptly to make very wide excursions to and fro in its vibrations. The point of maximum excursions, and the reading on the dial at this point, represent diastolic pressure. The palpation method, however, is subject to so many errors that it has been almost entirely supplanted by the auscultation method.

Auscultation Method. For this procedure a stethescope with a small flat transmitter is required. Neither the pulse nor the character of the needle vibrations need be regarded here, except as confirmatory data, since the reading of the pressure depends wholly upon the sounds heard through the stethescope.

Place the transmitter of the stethescope firmly over the artery just above or just below the inner bend of the elbow, with the ear-pieces in your ears. Inflate the cuff, as described above until absolutely no sounds are heard in the stethescope. Slowly allow the air to escape. The first sounds to be heard are dull, indistinct, irregular beatings, which may be disregarded, as they are due to the vibrations of the cuff. Continuing to deflate slowly, the sounds suddenly change to sharp, loud,

rhythmical clicks. The point where this change takes place denotes the point of systolic pressure, and should be read on the dial. Again continue deflating, until the sharp clicking sounds abruptly change to soft blowing sounds. The place where this first occurs, and the reading on the dial, represent the diastolic pressure.

We have, then, four phases in this process, namely:

(1) The phase of silence, signifying arterial collapse,

(2) The phase of indistinct, irregular sounds, having no clinical significance,

(3) The phase of sharp, clicking sounds, denoting systolic pressure,

(4) The phase of soft blowing sounds, denoting diastolic pressure.

NORMAL PRESSURE.

The normal blood pressure varies within the range of several millimeters, both systolic and diastolic, in different individuals so that only an approximate average can be given. It also varies with age, due to the progressive loss of elasticity in the artery walls, and the increase of heart muscle which compensates for the rise in resistance.

In a young male adult of 20 years the average normal diastolic pressure is about 70 mm., systolic 100 mm. From that time on the diastolic pressure rises approximately 0.5 mm. for each year of life, and the systolic about 1 to 1.25 mm. for each year. This, however, as stated, is subject to considerable variation within the normal. Females usually have slightly lower pressure than males.

It will be seen that the difference between diastolic and systolic pressure (representing the pulse pressure) widens each year, as the systolic pressure increases by a greater ratio than the diastolic. The heart is obliged to put on an excess of muscle power in order to overcome the increased resistance of the vessels.

PHYSIOLOGIC VARIATIONS.

Everything else being equal, blood pressure is raised by anything which increases either the force of the heart or the resistance in the vessels, or both. It is lowered by anything

which decreases either or both of these factors. Practically all physiologic elevations of pressure are brought about by increased heart action, either through muscular exercise, making an increased demand on the heart, or through mental excitement, producing an increased quantity of pressor internal secretions which stimulate the heart. The vaso-motors, by contraction, cause local rises of pressure, but normally they do not affect the general systemic pressure. Sleep and the recumbent posture lower systemic pressure by quieting the heart.

Physiologic elevations of blood pressure manifest themselves almost wholly in the systolic phase; that is to say, they are really increases in the pulse pressure. A normal person may take the most vigorous exercise, or undergo the most marked mental excitement, without any perceptible change in his diastolic pressure. Such elevations, moreover, are transient; they quickly subside as soon as the cause is removed.

PATHOLOGIC VARIATIONS.

Pathological variations of blood pressure follow the same rule as physiological, namely, elevations are caused by any conditions which increase either the force of the heart or the resistance of the vessels, low pressures by those which diminish either or both of these factors.

HYPERTENSION.

High blood pressure due to increased heart force, even when the cause is pathologic, usually manifests itself in the systolic phase only, i. e. it is an increase of pulse pressure; and tends to fall back to normal when the cause is removed. High pressure of this type is usually found in (1) acute toxemias, which violently stimulate the heart muscle, known as asthenic fevers, and (2) certain diseases involving the ductless glands, where there is either an excess of pressor secretions or a deficiency of depressor secretions thrown into the blood, acting upon the heart by way of the sympathetic nerves.

High pressure due to increased resistance in the vessels manifests itself primarily in the diastolic or static phase, later and secondarily in the systolic. There is but one explanation of a marked and continuous elevation of static pressure, namely, a long-continued absorption of low-grade toxines,

which do not stimulate the heart, but which gradually replace the elastic tissues of the vessels with inelastic, fibrous tissue (arteriosclerosis), thus increasing their resistance to the blood-stream. To cope with this increased resistance, the heart is obliged to develop a progressively increasing amount of energy, (which it does by enlarging its muscle), so that these cases eventually exhibit very high systolic pressures. The systolic pressure, indeed, rises in a much greater ratio than the diastolic.

The important feature in such cases, however, is the static hypertension. The high systolic pressure is a compensatory process. A patient whose static pressure is high, showing increased resistance in the vessels, must develop a proportionately high pulse pressure in order to function adequately. The gravest cases of all are those in which the static pressure is high and the pulse pressure is not proportionately raised, showing that the heart is not compensating for the increased resistance. Such a state of affairs is a sign of a weakened, failing heart, and is the precursor of disaster.

HYPOTENSION.

Low blood pressure is generally due to certain low-grade chronic infections which weaken, without hardening, the walls of the vessels, and also the heart muscle. All the asthenic fevers do this temporarily—typhoid, typhus, diphtheria, etc. Tuberculosis is the chief permanent cause of low pressure. It is also found in certain diseases involving the ductless glands, in which there is either an excess of depressor or a deficiency of pressor secretions, as in certain types of goitre, premature menopause, etc. Both static and dynamic pressures are usually low, and the pulse pressure as well.

BLOOD PRESSURE AND THE EYE.

The eye bears a direct and intimate relation to conditions of blood pressure, especially to hypertension, and this relation may be said to have two general modes of expression:

(1) The disturbed tension, **per se,** impairs the functioning of the eye,

(2) The structures of the eye share in the pathologic processes which cause, and which result from, the disturbed tension.

1. Hypertension, especially, impairs the functioning of the eye, both as to its muscular and its retinal elements, causing insufficiency of accommodation and diminished visual acuity. Even the temporary high pressures due to physiologic causes frequently produce transient disturbances of this kind. Almost everyone has experienced blurred vision, and especially inability to read at near point, for quite a few minutes after engaging in violent exercise, until the heart quiets down and blood pressure falls again.

In pathologic hypertension the ocular disturbances are less turbulent, because the high pressure, as a rule, comes on gradually, so that the patient often has no subjective knowledge of visual deficiency, or attributes it to error of refraction, until a visit to the refractionist and a test of the blood pressure reveals the true state of affairs. On the other hand, the ocular effects of pathologic hypertension are more permanent and far-reaching than those of physiologic elevations; and, as a matter of fact, the eye is one of the earliest organs to experience the ill consequences of high blood pressure, because the high elastic coefficient (incompressibility) of the vitreous permits the high pressure in the ocular arteries to be transmitted almost in full to the ciliary body and the retina.

Insufficiency of accommodation (premature presbyopia) and low visual acuity, then, may be, and often are, due to sheer hypertension, i. e. increase of pulse pressure, where the static pressure is normal, and no destructive processes are present or discernible either in the eye itself or in the systemic vessels. And—what is of great importance to the refractionist—these visual disturbances, due to high pressure, are quite often amenable to help by lenses, affording a source of deception and misleading to both operator and patient. A hyperope, for instance, who, by reason of hypertension, is unable to perform proper facultative accommodation, may very easily be enabled to read well at 20 feet by means of plus correction; or a patient whose reading accommodation is deficient because of hypertension may well be enabled to read with ease by plus lenses; thus deluding the refractionist into the idea that he has remedied the trouble.

It may be laid down as a rule of practice, therefore, that when insufficiency of accommodation and poor visual acuity are associated with high blood pressure, the latter condition is to be dealt with before the refractionist's work can be adequately performed.

Hypotension, **per se**, does not, as a rule, produce any distinctive ocular symptoms. The eye shares with the rest of the organism in the poor nutrition due to low pressure, so that it is quite possible to have accommodative insufficiency from hypotension as well as from hypertension. The retina is quantitively anemic, and therefore not so keen in its reactions as normally. And the extrinsic muscles, being weak, show lowered duction powers. But in many patients with low blood pressure no abnormal functioning of the eye is discoverable.

2. When hypertension is the outcome of increased resistance in the blood vessels, manifesting itself primarily in the static phase, then, sooner or later, the vessels of the eye share in the pathologic process which underlies the whole disturbance, and in addition to the disturbances due to the high tension, we have a train of organic disease in the eye which still further, and more seriously, interferes with vision,—arteriosclerosis, retinitis, retinal hemorrhages, retinal thrombosis, choroiditis, etc. No doubt many cases of glaucoma have their rise in such conditions.

All of the chronic infectious diseases which harden the blood vessels and raise the diastolic pressure sooner or later register themselves in the eye. Nephritis, syphilis, gall-bladder infection, gastro-intestinal toxosis, pyorrhea, all these and many others are in this class. The eye, being an end organ, (i. e. a terminal loop in the circulatory system), is bound to suffer from toxemia; often it is the earliest organ to give subjective notice of the trouble; and quite frequently such conditions are discovered in the eye-ground before there are any subjective symptoms at all. In all such cases, the finding of a high blood pressure (static) confirms the evidence of the ophthalmoscope.

Hypotension is much less often associated with organic disease of the eye than hypertension. Most low pressures are due to disturbances of the internal secretions, and these do

not become organic. Occasionally a continued fever of the asthenic type, like typhoid, produces retinal and ciliary troubles. Anemia, from whatever cause, is attended by retinal anemia, sometimes even to the point of tiny hemorrhages. In general, however, it may be said that long-continued low pressure, associated with organic changes in the ocular structures, indicates tuberculosis.

Bodal's Test. A test for color vision by means of colored blocks.

Bowman's Membrane. The second layer of the cornea, immediately under the external epithelium. It is also known as the external limiting membrane.

Bozzi's Foramen. Macula lutea of the retina.

Brachymetropia. This term (literally, a shortness of the eye) denotes the physical condition of the eye which constitutes hyperopia.

Bulbus Oculi. The eyeball.

Bumke's Pupil. Dilatation of the pupil in response to psychic stimuli. It is absent in dementia precox.

Buphthalmia. Same as buphthalmos.

Bupthalmos. Congenital glaucoma, hydrophthalmos, keratoglobus; increase of intraocular fluid, producing enlargement of the eye.

Burns' Amaurosis. Amaurosis due to sexual excesses. See Amaurosis.

Butler's Shield. A watchglass so fastened to adhesive plaster as to protect the unaffected eye in case of purulent ophthalmia.

Caecitas. Blindness.

Camera. Another name for the chambers of the eye.

Campimeter. An instrument for determining the field of vision. See **Perimeter.**

Canals. These are tiny channels in the eye which lead from one open space into another. They are named as follows:

Central Canal. A slightly compressed tubular channel 1 to 2 mm. in diameter, from the retinal papilla to the posterior pole of the lens. This canal, in the adult, is usually a blind duct, being the remains of the fetal channel which conducted the hyaloid artery. Occasionally the artery itself persists in the adult.

Hyaloid Canal. Same as the central canal.

Lacrymal Canal, or Ducts. A channel running from the lower palpebral sac, a few mm. from the inner canthus, to the inferior meatus of the nose. The canal is really a combination of two ducts, which are continuous with each other,—the lacrymal duct, in soft tissue, from the sac to the superior maxillary bone, and the nasal duct, through the maxillary bone, from there to the meatus. Its purpose is to drain the tears from the eye.

Canal of Cloquet. Same as the central canal.

Canal of Petit. A supposed canal extending about the crystalline lens in the folds of the suspensory ligament.

Canal of Schlemm. A circular canal, in the deep scleral tissue, surrounding the cornea. It is supposed to be a part of the lymphatic system, although there is a great deal of controversy concerning it.

Canal of Stilling. Same as the central canal.

Canthoplasty. Any operation which has for its object changing the condition of the eyelid.

Canthororrhaphy. An operation for sewing the eyelids.

Canthotomy. Slitting of the canthus.

Canthus. The angle made by the junction of the upper and lower eyelids. The one on the nasal side is called the inner, and the one on the temporal side the outer, canthus.

Capsule. A sac, or membrane, which surrounds and contains an organ or tissue. The capsules of the eye are as follows:

Bonnet's Capsule. See Capsule of Tenon.

Capsule of the Lens. The sac which surrounds and contains the crystalline lens. Its index of refraction is 1.39. It is made of elastic fibres which permit of a change of curvature when the ciliary muscle contracts (see **Accommodation**) but which gradually lose their elasticity as age advances until this change is no longer possible. In operations for cataract the capsule is usually opened and the lens extracted from it; the capsule then absorbs.

Capsule of Tenon. A delicate membrane which surrounds the eyeball from the optic nerve posteriorly to within a few millimeters of the corneal ring anteriorly.

Capsulotomy. Incision through the capsule of the lens in an operation.

Cardinal Points. See **Points.**

Cartilage, Tarsal. The stiff tissue between the skin and the muscle of the eyelid which gives it shape and support.

Caruncula. A small reddish body near the inner canthus of the eye.

Cast. A lay term for strabismus.

Cataphoria. A state of muscular imbalance in which the eye tends to turn downward, due to the dominance of the inferior rectus muscle. (See **Heterophoria.**)

Cataract. The crystalline lens, being a part of the refracting media of the eye, must necessarily be transparent in order to function properly. Under certain pathologic conditions, which are not always well understood, the lens loses its transparency, and becomes yellow and opaque, causing, of course, a degree of blindness proportionate to its opacity. This condition is known as cataract.

CAUSES OF CATARACT..

As intimated, it is not always easy, or even possible, to determine the underlying cause in a given case of cataract. Its primary cause, to be sure, is interference with the nutriment of the lens; and the peculiar anatomy and physiology of the lens, i. e. its lack of blood supply and the derivation of its

nourishment from the surrounding ciliary body, renders it very susceptible to such interference.

It has recently been determined, beyond question, that one of the principal causes of the origin of cataract is the influence of light which is rich in ultra-violet rays, such as daylight, which interferes with the nutrition of the lens, not by direct action, but through the optical heterogeneity of the lens, which disperses a part of the ultra-violet rays to the ciliary processes, damaging their epithelium. That this can only be a primary, and not an underlying cause, however, is evident from the fact that everyone who is exposed to white light does not by any means acquire cataract.

As contributing causes may be assigned, in general, all conditions which impair the nutrition of the body as a whole, among which must be included old age, and those which impair the local nutrition of the lens itself. In the first class of cases, in addition to senility, we have certain systemic diseases, notably diabetes, nephritis, heart disease, arteriosclerosis, autotoxemia, malaria; in the second class, blows upon the eye (either as an immediate or a remote effect), violent inflammations of the anterior portion of the eye, myopia of high degree, retinitis pigmentosa, chorioditis, glaucoma.

VARIETIES OF CATARACT.

Cataracts may be classified according to (1) their pathology, or (2) their position and structure.

(1) According to their etiology and pathology, the principal forms of cataract are:

(a) Congenital. Caused by disturbances of development or by an inflammation of the eye in utero. Usually bilateral (in both eyes), and frequently inherited. They are not usually made out until the child is some weeks old.

(b) Senile. By far the commonest form. Rarely occur before fifty years of age, but occasionally between forty and fifty. Usually affect both eyes, but seldom at the same time, one eye being usually ahead of the other in its development. The mere fact of a cataract occuring in an old person, of course, is not sufficient to diagnose a senile cataract, as an old person may have cataract due to other causes.

(c) Diabetic. Always bilateral, and often soft in character, i.e. show no disposition to harden or ripen.

(d) Glaucomatous. Due to the increased tension of glaucoma. Generally unilateral, as glaucoma is.

(e) Complicated. This form is due to, and complicated with, inflammations of the eye or degenerative processes. Glaucomatous cataracts really belong in this variety, but for clinical reasons are considered separately.

(f) Traumatic. In this class we do not include those cataracts which occur as the remote effects of injury, but only those which result directly and immediately from rupture of the lens capsule, by a blow or other injury. The aqueous humor enters the capsule, attacks the lens substance, first causes it to swell and become cloudy and opaque, and finally absorbs it.

Classified according to their position or area, the most commonly met forms are:

(a) Anterior Polar, situated in the anterior pole of the lens.

(b) Posterior Polar, located in the posterior pole.

(c) Nuclear, situated in the nucleus of the lens.

(d) Perinuclear, or Lamellar, due to cataract lying between the nucleus and the cortex. Usually stellar in shape. The most frequent form in children.

(e) Circumscribed, in which there are limited opacities of various shapes within the lens, chief of which are central, where there is a small spherical opacity in the centre of the lens; fusiform, where the opaque lines run in spindle fashion in the direction of the axis of the lens; and punctate, where there are several spots distributed through the lens.

The above classification of area applies, as a rule, only to the starting-place of the cataract, as all cataracts tend to spread until they occupy the entire lens.

STAGES OF CATARACT.

Various well-defined stages in the development of cataract are recognized as follows:

(a) Incipient. Where the opacity has not yet reached the stage of definite outline. In this stage the cataract can usually be diagnosed only by indirect means, especially by the

inequality of refractiveness of different portions of the lens, as shown by the ophthalmoscope.

(b) Intumescent. The stage, after the definite establishment of opacity, during which the cataract is ripening, i. e. until it reaches the anterior capsule. During this stage a light held near the eye, to one side of it, throws a shadow of the iris.

(c) Mature. When the anterior chamber again becomes of normal depth and the iris no longer casts a shadow. The cataract now has become total, and is ready for extraction.

(b) Hypermature. If a cataract is allowed to remain after becoming ripe, one of two things happens to it: (1) It loses water and becomes shrunken and disintegrated, and the anterior chamber becomes deeper and deeper, or (2) It grows more fluid in proportion as it breaks up into smaller parts, so that at last there is a central mass of solid surrounded by fluid (Morgagnian cataract).

SYMPTOMS.

The subjective symptoms are, of course, disturbances of vision, varying with the nature and stage of the disease. Often, in the incipient stage, there is multiple vision, due to the optical irregularities. Later, there are scotomata corresponding to the areas of opacity, or general diminution of vision, if the cataract is disseminated. Eventually, there is complete blindness to all but light.

Objectively, the earliest sign of cataract is often the demonstration of myopia in a formerly emmetropic or hyperopic eye, due to swelling of the lens ("second sight"), or differences of refractivity in different parts of the crystalline lens, shown by the ophthalmoscope. Later, the opacities can be demonstrated, showing gray under oblique illumination, black with the ophthalmoscope. Anterior and posterior polar cataracts are differentiated by the parallax motion; on rotating the ophthalmoscope, anterior opacities move with, posterior against, the mirror.

When the cataract is ripe, the patient should still be able to perceive a moderately bright light (perception) and to indicate the direction from which the light is coming (projection).

If these two faculties are present, one may hope for good vision after the cataract is extracted.

TREATMENT.

If taken in its incipiency, the progress of a cataract can undoubtedly be checked, in some instances, by the wearing of amber lenses, to protect the eye from white light, and the instillation of dionin, to promote absorption and nutrition. Seldom, however, do cataracts come under observation in time to carry out this abortive treatment; and practically all cataracts progress, in spite of all treatment, to completion, where extraction is the only available remedy. The time required for their ripening varies considerably, all the way from a few months to two or three years.

In the meantime, great assistance and comfort can be given the patient by a careful refraction of the eyes, and the prescribing of suitable glasses, changing them from time to time, as the changes in the eyes require, until blindness becomes too pronounced for any lenses to help. As stated above, the general tendency of cataract is to make the eye more myopic than it was before. At the same time it impairs the elasticity of the accommodative mechanism, so that the patient usually needs more than ordinary presbyopic correction. By skillful attention to the patient's refractive needs, useful vision can be prolonged far into the course of the disease.

The task of extraction belongs, of course, to the oculist, and is far too long and complicated a subject to go into here. The reader is referred to a work on ocular surgery.

After extraction the real work of the refractionist begins. It then becomes necessary to furnish the patient with a plus lens which will compensate, optically, for the loss of the crystalline; and to this must, in practically every case, be added cylindrical correction to remedy the astigmatism due to the cicatrisation of the wound in the cornea. Since the adoption of the scleral incision, this astigmatism is not so frequent or so marked; but many operators still use the corneal incision. It is best not to attempt final refraction of the eye until several months after operation, so as to permit it to settle down to its permanent state.

Cataract-Spoon. An instrument shaped like a spoon, used for removing the lens.

Catatropia. An unusual muscular anomaly in which a hypotropia of one eye alternates with that of the other.

Catoptrics. That branch of optics which deals with incident and reflected light, based upon the law that the angle of incidence and the angle of reflection are equal.

Catoptric Test. A test to determine the presence of a cataract by reflection of light. If a candle be held about a foot from the eye, about 30 deg. from the optical centre, and the observer stand the same distance on the opposite side, if no cataract be present, three images of the candle-flame will be seen, one reflected by the surface of the cornea, one by the anterior surface of the lens, and one by the posterior surface of the lens; if there be cataract, the latter image will of course be missing.

Cat's Eye Pupil. A pupil the aperture of which is horizontally long and narrow.

Caustic. In optics this name is given to a curve to which the rays of light reflected or refracted by another curve are tangent. Caustics are therefore of two kinds, catacaustics, being caustics by reflection, and diacaustics, being caustics by refraction.

Cavascope. Device for lightng the interior of cavities.

Cecita. Blindness, same as cecity.

Cedmatophthalmia. Ophthalmia caused by rheumatism.

Celoscope. Instrument for illuminating cavities of the body.

Centimeter. One-hundredth part of a meter. Ten millimeters. Equivalent to about two-fifths of an inch.

Centrad. The hundredth part of a radian, used as a unit of measurement in prismometry. See **Prism.**

Centrage. Designating a condition in which the center of all the refracting surfaces of the eye take a position in one straight line.

Centrophose. Sensation of a central dark spot along the line of vision.

Centre. There are but two geometric figures which can properly be said to have a centre—the circle in plane geometry, and the sphere in solid geometry. Centres, in optics, therefore, are points in the centre of spherical bodies or systems, or, in the case of segments, at the centre of the spheres of which they are segments.

Centre of Curvature. The center of the sphere of which a lens curvature is the segment.

Optical Centre. The point where the secondary axes of a refracting system meet and cross the principal axis. This corresponds to the geometric centre of the refracting system considered as a single sphere. In thin lenses, and for practical purposes of calculation, the nodal points are virtually coincident with and constitute the optical centre. (See **Point, Nodal**).

Centre of Rotation. The point around which the eyeball is supposed to rotate under the action of the extrinsic muscles. The location of this point is a matter of uncertainty.

The word Centre is also used as a verb in optics, signifying to place the lens before the eye, or in its mounting, in such a way that the visual axis (q. v.) will pierce the optical centre of the lens. This is routine. More interest attaches to those cases in which it is desired to place the lenses before the eye so as **not** to be centered. (See **Decentering**).

Again, the word Centre is employed in connection with the nervous system to describe the point in the brain or spinal cord from which a nerve arises or in which it terminates.

Centrifugal. A term applied to a set of radiating forces which act from the circumference toward a common center out toward the circumference. Centrifugal light waves are plus waves.

Centripetal. Applied to a set of radiating forces which act from the circumference toward a common center. Centripetal light waves are minus waves.

Ceratocele. Bulging of the cornea due to a tumor.

Cerebroscope. Cerebroscopy. Applied to the use of the ophthalmoscope for the purpose of diagnosing conditions of the brain.

Chalazion. Infection and enlargement of a meibomian gland, (q. v.). Also called a meibomian cyst, and a tarsal cyst. Usually appears on the margin of the upper lid. Diagnosis and treatment belong to medicine. They seem to be at least aggravated by errors of refraction.

Chambers. The spaces in the eye between the cornea and the anterior surface of the lens, containing the aqueous humor. The anterior chamber extends from the cornea to the iris, the posterior chamber from the iris to the lens. Many anatomists deny the existence of the posterior chamber, stating that there is but one chamber, extending from the cornea to the lens.

Check Ligaments. See **Ligaments.**

Chemosis. Swelling, or edema, of the eyelid by the extravasation of blood serum into the loose tissue. It is a symptom of some other underlying trouble, for the medical man to discover.

Chiasm. The place where the partial decussation of the optic tract takes place. As the fibres of the optic nerves from the two eyes proceed backward to the brain, those which originate at the inner half of each retina cross over to the opposite side, while those which come from the outer half of each retina proceed on the same side. Thus, after passing the optic chiasm, the entire lateral half of each retina is represented on the corresponding side of the brain. There are a few nerve fibres which, at the chiasm, cross over and go back to the eye on the opposite side. These are called consensual fibres and are responsible for the consensual reflex. (See **Reflexes.**)

The optic chiasm is a most interesting and important point in the optic tract. Injury to the chiasm, or tumor of the chiasm, usually gives half-blindness on the nasal half of each retina, because such injury or growth is usually in the middle of the chiasm, affecting the inner optic nerve fibres as they cross. (See **Optic Tract.**)

Chiasmal Image. According to Prentice, "a strictly figurative image consisting of that orderly assemblage of the optic-nerve fibrils, within the cross-sectional and comparatively small area of the optic chiasm, which receive their individual stimuli from corresponding points in each retinal image." He deduces the rule that for 1 prism dioptre of deviation of the visual axes there is a separation of 0.15 mm. between the chiasmal image-centers.

Chiastometer. An instrument devised by Landolt for determining the distance between the two eyes during convergence.

Chionablepsia. Snow-blindness.

Chloropia. Vision in which objects appear green.

Chloropsia. Same as chloropia.

Choked Disc. See **Disc.**

Chorea. See **St. Vitus' Dance.**

Choriocapillaris. The middle layer of the choroid coat.

Chorioretinal. Pertaining to the retina and the choroid coating of the eye.

Choroid. Chorioid. A part of the second, or vascular tunic of the eyeball, lining the sclera from the optic nerve head to the ciliary body, with which it is continuous. It is closely attached to the sclera at the optic nerve, at the posterior pole (where the posterior ciliary arteries enter) and at the equator (where the venae vorticosae leave the globe). Lying immediately behind the transparent retina, it forms an important part of the fundus picture seen with the ophthalmoscope.

The choroid consists of five layers, as follows:

1. The Suprachoroid, a non-vascular, pigmented membrane between the choroid and the sclera.

2. Layer of Larger Vessels, chiefly veins, the interspaces being abundantly filled with brown pigment.

3. Layer of Medium-sized Vessels. This layer is extremely thin and only slightly pigmented.

4. Layer of Capillaries. This layer has no pigment.

5. Lamina Vitrea, or Basalis, a homogeneous membranous coating over the choroid.

The blood supply of the choroid is obtained principally by way of the short posterior ciliary arteries. A few branches from the long posterior ciliaries reach it. The blood flows off from the choroid by numerous veins, which keep coalescing to form large trunks, eventually combining into four or five vortices behind the equator, and these, in turn, empty into the two venae vorticosae, which penetrate the sclera and leave the eyeball.

The pigment with which the uveal structures are so abundantly supplied is well represented in the choroid. Here the pigment is of a yellow-brown color, which helps to give the characteristic hue to the fundus.

Choroido-Cyclitis. Inflammation of choroid and uveal tract.

Choroido-Iritis. Inflammation of choroid and iris.

Choroido-Retinitis. Inflammation of choroid and retina.

Chromasia. Color effect produced by chromatic aberration in functioning of lenses.

Chromatelopsia. A pronounced degree of color blindness.

Chromatherapy. Treatment by means of lights of different colors.

Chromatic Aberration. See **Aberration.**

Chromatic Audition. Literally, color-hearing. A phenomenon in which, along with the sensation of hearing, there emerges also a sensation of color. For a full discussion of this interesting phenomenon the reader is referred to a work on psychology.

Chromatic Dispersion. The splitting of white light into its composite color waves by the action of a prism, as in the spectrum.

—Anomalous. That in which the colors are spread out in an order differing from that of the regular spectrum.

—Irrational. That in which the dispersion of the extreme colors of the spectrum is not constant for different media.

—Partial. As relating to any pair of fixed lines in the spectrum, for a given substance.

—Mean. As relating to two definite lines of the spectrum.

Chromatic Test. This refraction test is based upon the chromatic aberration of the eye, which is exaggerated when the focal point of the eye is either behind or in front of the retinal plane, i. e., when the eye is either hyperopic or myopic. The aberration is accentuated and made subjectively perceptible by means of a cobalt lens, which cuts out all the color waves except the two extreme colors, red and violet, i. e., the waves of least and greatest refrangibility. The gradual merging of the intermediate colors being thus destroyed, a sharp distinction is perceived between the focussing of these two colors.

The following rules have been given:

With the cobalt lens before the eye, the patient's attention is directed to a small circular light, usually at infinity.

In hyperopia, the violet waves focus on the retina, while the red waves are still unfocussed; hence the patient sees a violet center with a ring of red around it; and plus correction is added until he sees no more red around the center, or until there is a slight blue ring.

In myopia, the red waves focus on the retina, while the blue waves have focussed and are diverging again by the time they reach the retina; hence the patient sees a red center with a blue ring around it. Minus correction is added until the blue ring disappears, or is very thin.

In hyperopic astigmatism, the patient sees red on each side, or in some other meridian. Add plus correction until the red on each side almost disappears, then minus cylinders, axis where the red shows, until the red appears at right angles to the axis of the cylinder, i. e., until a red ring appears around the center. Now add plus spheres until there is no longer a red ring, but a narrow blue ring.

In myopic astigmatism, the patient sees blue on each side corresponding to the two chief meridians, and minus cylinders are to be put on until there is a red ring around the center as

above, after which plus spheres are to be added until there is no red ring, but a narrow blue one.

In mixed astigmatism, the patient sees blue up and down and red on each side, or vice versa. Put on plus spheres until there is a little red left in its place, then minus cylinders, axis where the red is, until there is a red ring. Thereafter proceed as above.

Chromatism. The quality of exhibiting chromatic aberration. (See **Aberration.**)

Chromatometer. An instrument for measuring perception of different colors. The principle is to compare two complementary colors, produced by a quartz plate cut at right angles to its optic axis between a Nicol's prism and an Iceland spar. The patient, if color blind, will find, on turning the prism that in a certain position the two complementary colors are equal, showing at once what colors are confounded by him. Rose and Helmholz both invented instruments of this kind, which Chibret improved by enabling them to give any desired degree of color saturation. (See **Color Blindness.**)

Chromatophobia. Fear of colors.

Chromatopsia. An abnormal condition in which the patient sees everything of a certain color. The various kinds of chromatopsia are named according to the color seen, as Chloropsia, Rhodopsia, etc., q. v.

Chromatoptometer. An instrument for measuring the intensity of color.

Chromophan. Retinal pigment.

Chromophose. A subjective sensation of a spot of color in the line of vision.

Chromotalopsia. Color-blindness.

Chromoptometer. Same as **Chromatometer.**

Ciclite. Same as **Cyclitis.**

Cilia. Hairs. In regard to the eyes, the eye-lashes.

Ciliary. Pertaining to the lashes. The word is also used in a descriptive sense to signify likeness to hairs, as the ciliary body, the ciliary muscle, etc.

Ciliary Body. The middle part of the second tunic of the eye, so called because of the hair-like appearance of its striata. It has its beginning in a flat portion (the orbiculus ciliaris) which is continuous with, and almost indistinguishable from, the choroid, except for a different arrangement of the vessels and the absence of the ciliary capillaries, which end at the ora serrata.

The largest portion of the ciliary body is the ciliary muscle, consisting of two portions, distinguished by the different direction of their fibres: (1) The external, known as Bruck's muscle, containing longitudinal or meridional fibres, running from the corneal boundary to the choroid, and (2) The internal, known as Mueller's muscle, containing circular fibres, which is the active factor in accommodation.

The ciliary processes are on the muscle, and consist of stroma containing pigment substance and an extraordinary number of blood vessels. The ciliary body is, in fact, the most vascular part of the uvea.

The inner surface of the ciliary body has three layers:

(1) The vitreous lamina.

(2) The layer of pigmented cells.

(3) The non-pigmented layer of cylindrical cells. The last two layers (pars ciliaris retinae) pass over to the posterior surface of the iris, where they are converted into the two strata of retinal pigment layer of the iris (pars iridis retinae).

The blood supply of the ciliary is derived from the long posterior and the anterior ciliary arteries; these arteries break into numerous twigs which pass to the veins. The larger veins pass backward to the venae vorticosae; others pierce the sclera, coming into view under the conjunctiva, near the corneal ring, and anastomose with the conjunctival veins.

Ciliariscope. An instrument for examining the ciliary region of the eye.

Ciliosis. A nervous twitching of the eyelid.

Circles of Dispersion. Figures produced on the retina by divergent and convergent light-waves which enter the eye when it is adjusted for neutral waves. Such waves, of course, are not represented on the retina by focal points, but by circles. These circles of dispersion take the form of the pupil.

Circles of Haller. Vascular circles in the eye.

Circumocular. Surrounding the eye.

Circum-Orbital. Surrounding the orbit.

Clinoscope. An instrument, devised by Stevens, for determining the declination of the vertical meridians of the eye. Although primarily an instrument of research, it is of some practical value in cases of paralysis of ocular muscles and in anomalous adjustment of the eyes.

Clonic. A term applied to muscular spasmodic contractions which alternate with periods of relaxation, in distinction from tonic spasms which persist continuously.

Cocaine. Alkaloid of coca leaves. A drug which produces local anesthesia, by paralyzing peripheral nerve endings. It is much used in eye work in a 4% to 10% solution. Incidentally, it dilates the pupil by paralyzing the ciliary nerves, but its effect is transient, and it is not used for this purpose.

Coddington Lens. A lens used for magnifying the anterior tissues of the eye, the cornea, etc., for examination.

Collargol. A colloid form of silver salt, used as a collyrium.

Collimate. To bring the axes of a binocular instrument into line.

Collimator. A part of a binocular instrument which brings the axes into line.

Collinear. Lying in the same straight line.

Collinear Space-Systems. The name given to a point to point system of uniting object-space and image-space by means of rectilinear rays. (See **Aplanatic.**) It is also known by the term Collineation, introduced by Moebius.

Colloid. A substance which in solution does not pass easily through a semi-permeable membrane.

Collyrium. A medicine to be used in the eye in the form of drops.

Colmascope. An instrument for showing strains in lens blanks. By transmission of powerful light the strain is shown by shadows and interference colors.

Coloboma. An absence, or a break in the continuity, of one of the vascular tissues of the eye, usually of the iris or the chorioid. Colobomata may be congenital, or acquired through injury or disease, or artificially produced by operation. Those of the iris are, of course, visible to the naked eye, the black pupil showing through the break. Those of the chorioid are seen with the ophthalmoscope as patches of white showing through the retina.

Color. This word, like the word "light," has two applications: a physical or objective application, and a physiological or subjective one. In the first use of the word we refer to the physical phenomena which are responsible for the production of color; in the second, to the impressions or sensations produced on the brain by the action of these phenomena upon the retina of the eye. It is to be noted, however, that the names and qualities which we ascribe to the physical phenomena are derived from, and determined by, the subjective sensations which they produce.

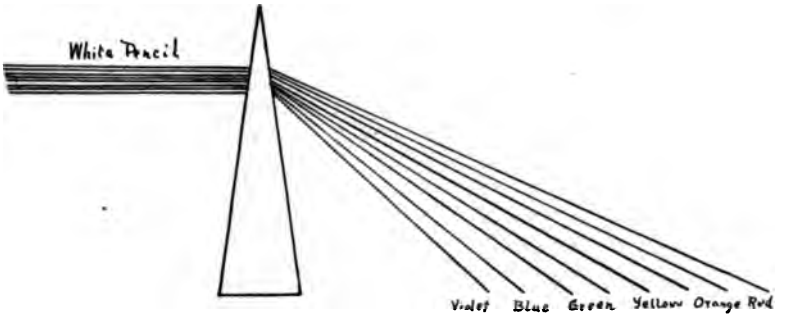
(1) Physically, color finds its equivalent in the number of oscillations per second of the various light waves; or, what is the same thing, the lengths of these various waves from crest to crest. Naturally, since color is, in the last analysis, a subjective sensation, forming an integral part of vision, only those light waves which fall within the range of retinal reaction, i. e., only those which stimulate the sensation of vision, can be regarded as being color waves.

It has been found by experiment that the slowest and longest of these visual light waves give the sensation which we call red; the fastest and shortest give the sensation of violet. Slower, longer waves than red (infra-red) and faster, shorter

waves than violet (ultra-violet), give no color sensation at all. About midway, as to wave-length, between red and violet are waves which produce the sensation of green; and intermediately between these three are gradations of wave-lengths which give a series of color sensations in which the red element gradually loses predominance and violet gradually assumes it.

All the different color waves are contained in a full beam of white light, so that it is customary to say that the sum of all the colors is white. This statement, however, can only be properly made from a subjective standpoint. Experiment has shown that each of the color waves is differently susceptible of refraction by a refracting medium; the violet waves being affected the most, the red the least, and so on, proportionately up or down the scale. This property makes it possible, by means of a refracting prism, to separate a beam of white light into its constituent color waves so that they fall upon a screen in a continuous row of colors, merging into each other, with violet at one end, red at the other, green in the middle, and the other colors in their respective orders. The same effect can also be produced, in even finer differentiation, by diffraction through a narrow slit in an opaque sheet of metal. The series of colors thus separated out is technically known as the spectrum; the instrument by which they are separated, the spectroscope.

The shorter the spectrum, i. e., the less space into which the colors are drawn out, the fewer gradations of color sensations made upon the eye; in other words, the fewer colors seen. In a short spectrum, looked at as a whole, there seem to be but four colors, red, green, blue and violet, because, by contrast with these decided colors the short transition colors disappear. When the spectrum is made longer, the transition colors are better recognized; although at no time does any color make its full impression on the eye while other colors affect it simultaneously. By means of an ordinarily long spectrum we are able to distinguish eight general color sensations, which, with their rates of oscillation and wave-lengths, are as follows:



Illustrating Dispersion of Color Waves by Prism

	Millions of Millions of Vibrations per second.	Wave Length in micrometers.
Extreme red	395	760
Red	437	686
Limit of red and orange	458	656
Golden yellow	510	589
Green	570	526
Cyanean blue	618	486
Limit of indigo and violet	697	430
Violet	757	396

(The above table is compiled from Helmholz and Abney.)

COMPLEMENTARY COLORS.

That there is a real difference between color as a physical phenomenon and color as a physiological sensation is shown in the fact that the falling, simultaneously, upon the retina of two or more certain color waves produces at least two colors which do not exist in nature, namely, purple and white. There is no part of the spectrum in which the wave-length is such that the corresponding color would be purple; it is a color sensation only, produced by the simultaneous impressions of blue and red. The same is true of the color sensation of white, produced by combining the effect of all the colors in the spectrum.

It is possible, however, to obtain white from combinations of two simple colors taken from different parts of the spectrum

and mixed in certain ratios. Two such colors are called complementary, a series of which is here given from Helmholz:

Color.	Wave Length.	Color.	Wave Length.
Red	656	Green-Blue	492
Orange	607	Blue	489
Golden Yellow	585	Blue	485
Yellow	567	Indigo-Blue	464
Green-Yellow	563	Violet	433

Green has no simple complementary color, but only a compound one—red and blue, or purple.

It should be borne in mind that what is here stated concerning colors relates only to pure colors of the solar spectrum, i. e., those which reside in a pure beam of white sunlight. As a matter of fact the colors in nature with which we have most to do—such as the colors of flowers, minerals, etc. —are almost never pure colors, and therefore are subject to variations from the behavior here attributed to the pure colors. When we come to deal with artificial pigments, we are confronted with even greater complications, due not only to the lack of purity in the colors, but also to the absorption and reflection which these pigments exercise upon the different color waves.

COLOR PROPERTIES.

Colors have three elements of quality, (1) hue, (2) purity, and (3) brightness. The first is its true color quality, giving the sensation of red, blue, etc., and depends upon the length and velocity of the wave; it corresponds to pitch in sound. The second (often called saturation) depends upon the admixture of white; the less white mixed with it, the purer the color, or the greater the saturation. The third quality, sometimes termed luminosity, depends upon the vigor of the ether movement which it produces, and is therefore proportional to the square of the greatest velocity of the ether particles. Subjectively, of course, a color may be brighter according to the sensitiveness of the retina to that particular color.

(2) The subjective, or physiological side of color is not as well understood as its physical side, and is in much dispute. It is generally assumed that the rods and cones of the retina contain different kinds of photo-chemical substances, each of

which reacts to a different wave-length of light, thus mediating the sensation of a different color. As to the details of the process there are several different theories.

The Young-Helmholz theory, originated by Thomas Young and elaborated by Helmholz, holds that there are three such retinal substances, reacting most strongly to red, green and blue wave-lengths, respectively, although each of them is slightly affected by all other waves. Single stimulation by light-waves of either of these substances, therefore, produces the single sensation of red, green or blue, as the case may be. All other color sensations are produced by mixed stimulation of two or more substances by two or more wave-lengths, in varying degrees of intensity. Thus:

Red stimulates strongly the red-sensitive substance, the green less, and the blue least of all. Sensation equals red.

Yellow excites moderately the red and the green-sensitive substances, the blue but little. Sensation equals yellow.

Simple violet excites strongly the blue-sensitive substance, the green less, and the red less. Sensation equals violet.

The Hering theory, of more recent date, also assumes three photo-chemical substances, but ascribes to each a two-fold action, namely, that under the influence of certain wave-lengths they undergo anabolic (building-up) changes, and under certain other wave-lengths catabolic (tearing-down) changes. The double color-sensation thus ascribed to the three substances are as follows:

White — Black
Red — Green
Yellow — Blue

Other color sensations, under the Hering, as under the Helmholz theory, are due to mixed stimulation.

The three color sensations of single stimulation predicated by the Young-Helmholz, and the six predicated by Hering, theories, are known as primary color sensations. Mixed sensations are called secondary color sensations.

COMPLEMENTARY COLORS.

It has already been said, when treating of the physical aspect of the subject, that it is possible, by combining certain pairs of colors of the spectrum, to produce a sensation of white;

and that these pairs were known as complementary colors. Subjectively, it is also to be observed that these complementary colors are mutually exclusive of each other in their excitation of color sensation; that is to say, if both wave-lengths fall on the retina simultaneously, it is impossible for the brain to perceive both of them. If one stimulation is in excess of the other, the brain will perceive the color whose stimulation is in excess, and not the other at all; if the two stimulations are equal in intensity, then each offsets the other, and the brain perceives no color at all, but white.

It must be confessed that the Young-Helmholz theory, which at present is the most generally held among physiologists, offers very scant explanation of this phenomenon of complementary and contrast colors. Hering, on the contrary, built his theory up implicitly out of a consideration of the behavior of these colors. His three primary-color pairs comprise the fundamental contrast and complementary colors. If either one of these photo-chemical substances be stimulated simultaneously by the two wave-lengths to which it reacts, the nature of the result will depend upon the comparative intensity of the two stimulations. If the anabolic stimulation is in excess, the reaction will be an anabolic one, and the color sensation will be that of the anabolic color; if the catabolic stimulation is in excess, the reaction will be catabolic, and the opposite color sensation result; if the two stimulations be equal, anabolism and catabolism will balance each other, no color sensation will result, and neutral white will be seen. But the substance cannot undergo both anabolic and catabolic changes at one and the same time; hence it is impossible to perceive both of the two contrast colors at once.

Subjectively, again, these complementary colors express themselves in characteristic after-images. If the eye gaze steadily for several seconds upon a primary color, especially in great saturation, and then either be closed, or else be fixed upon an area of neutral tint, an area of complementary color will be seen similar in size and shape to that of the primary color first looked at. Thus, if one first looks at red, the after-color will be green; if blue, then yellow.

Helmholz explains this on the ground that the photochemical substances of the retina are fatigued by first viewing the primary color, so that when the eye is directed to neutrality it sees only a combination of the other two. Thus, by looking at red, the red-sensitive substance is temporarily exhausted, so that as an after-color the eye can only see green and blue. Hering's explanation is that the after-color sensation is produced by the building up of the substance which had been previously disintegrated, or vice versa.

It is known, in a general way, that the various color waves, if made to fall continuously for long periods of time upon the eye, produce characteristically different physical effects upon the tissues of the eye, not only the retina, but other parts. It is a subject, however, which has not been very systematically studied, and has yet to be investigated. We have learned the benefits of keeping out of the eye, in certain cases, the actinic waves (ultra-violet), by means of certain qualities of lenses; but differentiation between the color waves themselves has not as yet been carried out to any great extent. Although numerous devices have been made to test the sensitiveness of the eye to different colors, no very practical application of them has yet been made.

Color Adaptation. The adaptation of the retina for the perception of colors on going from a relatively light room into a relatively dark one, or the reverse. The subject has been extensively investigated by Eldridge-Green.

Color-Blindness. This condition was discovered and demonstrated by Dalton, an English physicist, who was himself a victim of it, and is sometimes called, after him, Daltonism. It consists in an inability to distinguish any, or certain, of the primary colors of the spectrum. In the first case it is said to be total color-blindness; such people (very rare) live their lives in a world of black-and-white and gray. In the second case it is called partial color-blindness; and persons of this type are much more numerous than was formerly supposed. According to the Young-Helmholz theory of color perception (see **Color**) we designate the person who recognizes only two primary colors a dichromate; one who recognizes but one a mono-

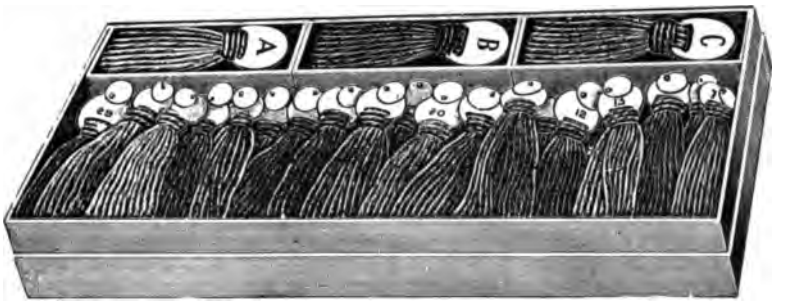
chromate. A normal person is a trichromate. These terms would hardly apply under the Hering theory.

The condition is generally supposed to be due to a lack in the retina of the chemical substance or substances which react to the stimulation of the particular color-waves to which there is blindness. Naturally, blindness to one color involves blindness to its complementary color, according to the theories of both Helmholz and Hering. And, in general, this is what we actually find in practice. The commonest form is blindness for red and green. However, there are certain findings in some cases of color-blindness which are not satisfactorily explained by either theory; and, in fact, no theory of color perception has yet been offered which accounts for all the normal and pathological phenomena.

In the commonest forms of color-blindness the two colors that are seen are yellow and blue, between which, in the spectrum, is a neutral grey area. Of such color-blindness there are two general types, (1) the so-called red-blindness, where the spectrum is seen shortened, at the red end, the shades of red appearing as dark areas, and (2) the so-called green-blindness, where the spectrum does not appear shortened. Under the Hering doctrine, both are classified as red-green blindness.

TESTS.

For the scientific testing of color-blindness a spectroscope is necessary, to determine whether or not the spectrum is shortened at the red end and, also, by isolating the bands of color, to discover how the patient regards and compares the single colors.



Holmgren's Color Test.

In 1875 Holmgren, of Sweden, introduced his well-known worsted test, based on a study of color-blindness with the spectroscope. Worsted was selected, first, because it has no gloss, and color-blind persons are not infrequently able to pick out colors by means of their characteristic glare, second, because in flat colors one can obtain a great degree of saturation.

The principle of the Holmgren test is that red- and green-blind persons see in the spectrum only two colors—yellow and blue, with a neutral gray band between them. Holmgren selected green as his first test-color because it is the whitest color in the spectrum and corresponds in tint to the neutral zone, thus making an excellent confusion color with pale shades of gray, brown, fawn and yellow. His second test color is rose, a mixture of red and blue, in which, of course, the red-blind see only blue. His third is red, which affords an excellent confusion with dark shades of gray, brown, etc.

The technique of the Holmgren test is as follows: The test set is to include three large test skeins, green, rose and red, and more than a hundred small skeins consisting of red, orange, yellow, yellow-green, pure green, blue-green, blue, violet, purple, pink, brown and gray, with several shades and tints of each color.

Test 1. Ask the patient to select from the entire collection (placed in good daylight) all the colors which, in general hue, seem to him to be like the large green skein. The completely color-blind will select, with or without greens, some confusion colors—grays, fawns, pinks, yellows, etc. The incompletely color-blind will match it with greens, to which they will add a few light shades of fawn or gray. This test indicates whether or not the candidate is color-blind—completely or incompletely. For further investigation we employ another test.

Test 2. Mix the colors up again, and ask the candidate to match the rose skein. The color-blind will select always the light or dark shades of blue and violet. The completely color-blind will choose blue or violet, with or without purple; the completely green-blind, green or gray, with or without purple. A patient proven color-blind by Test 1 is only incompletely so if he matches rose with deeper purples alone.

Test 3. This is a supplementary test for separating out the reds, by having the candidate match the red skein. The red-blind will select, beside reds, shades darker than red; the green-blind, green and brown shades lighter than red. Only markedly color-blind persons fall down on this test.

The Jennings Self-Recording Test is a modification of the Holmgren, devised by J. Ellis Jennings, of St. Louis, Mo. It consists of a square box, divided into two compartments, one for the Green test and the other for the Rose test. The stand-

Jennings' Self-Recording Test.

ard test skeins of green and rose, respectively, are attached to the inside of the box-lid. In each side of the box is a color-board made up of green and all the green-confusion colors, on one side, and of rose and all the rose-confusion colors on the other side. In the center of each color-patch is a perforated hole, through which the candidate thrusts a stylus to register his selection of a match-color. Beneath the color-board is a record-sheet, divided into squares corresponding to the color-patches, and marked with a G and an R, respectively, in those squares which coincide with a color-patch which matches the green or the rose.

If the candidate be normal, there will be a punch-mark on the record-sheet in every space marked G and R. Any punch mark in a blank space indicates a mistake. If the mistake is on a horizontal line with the letter G, the mistake was made in the green test if horizontal with the letter R, in the rose test.

Williams Lantern.

Williams' Lantern Test. The lantern test differs from, and supplements, the worsted test in that (a) it tests the color perception in the central retinal area, where light from a distant lantern focusses, and (b) it determines the ability of the candidate to recognize and name the colors of signals which he will have to use at night. In the worsted test no names are used; only comparison of colors. It is, however, important that the candidate (if he be a man using signals) be able to give to color sensations the names which normal persons give to them.

The lanterns, screened by shutters, are lighted in a darkened room, and the colored glasses made to face him directly. By means of revolving shutters, the colored lights are then revealed to him, usually two or three at a time, in a sequence corresponding to the standard record form used, and he is required to call out their names. Where he gives the name of the color correctly, the examiner writes an O, or O. K., against it on the record; where he names it wrongly, he writes in the name which the candidate gives. In this way he is able to interpret the completed record sheet.

A candidate should be rejected:

If he calls a red light green or white;
If he calls a green light red or white;
If he calls a white light red or green.

Bearing in mind, as stated above, that candidates are sometimes able to differentiate colors by their luminosity, the lantern test should provide for varying the intensity of the lights, so as to remove this possible source of malingering.

When cobalt blue glass is used in the test, it is to be remembered that hyperopic candidates will see this color as a center of blue with a red center; myopic candidates as a center of red with a blue margin. (See **Chromatic Test**.)

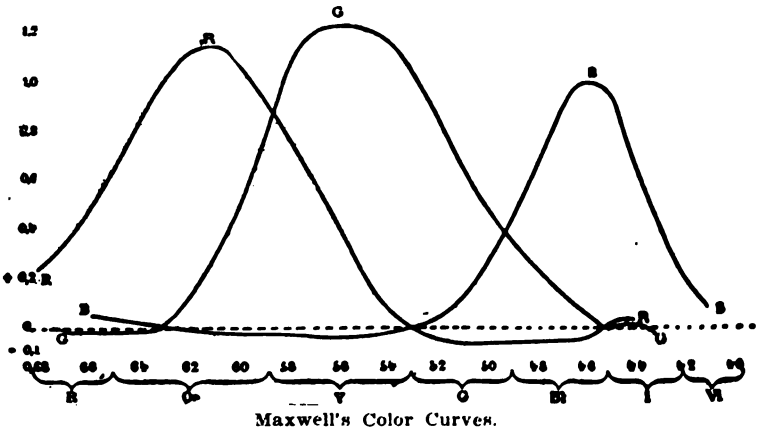
In making the lantern test it is important that the examiner make no remarks which will indicate whether the candidate's answer is right or wrong.

Nagel's Test consists of a set of cards, each bearing a series of little color disks arranged in a ring. In some rings the disks are all of the same color but in different shades; in others there are two or three different colors. By asking the patient to indicate which are monochromatic, which dichromatic, and which trichromatic, we readily ascertain the existence and nature of his color-blindness.

The Stilling Plates consist of patterns set on a back-ground of different color, the tints being such that a color-blind person cannot distinguish the pattern from the back-ground.

Eldridge-Green, of London, has also devised a system of lantern tests. The colors yellow, pure green, signal green, blue, purple and red are mounted on three discs; a fourth is ground glass with white light. The discs are rotated, being brought before the lamp in succession, or any desired combination formed. A diaphragm imitates the representation of railway signals.

Color Curves, Maxwell's. Three curves representing the three primary colors, whose points of intersection with the vertical



Maxwell's Color Curves.

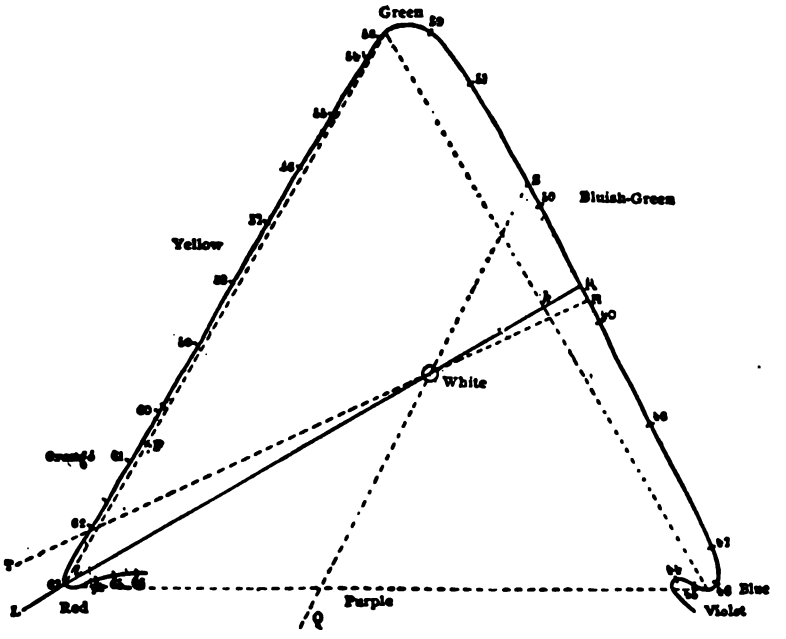
represent the relative amounts of each color needed to produce the required mixture.

Color Mixture. This term has two meanings, (1) By the physicist it is used to designate the simultaneous presentation to the brain of two color sensations, (2) By the painter it is

employed to indicate the resultant color effect of mixing two or more pigments.

Colored Shadows. Paradoxical shadows cast by an opaque body on a neutral screen from two equi-distant lights of equal intensity, one being white and the other colored. The shadow cast by the white light appears to be of the color of the colored light, while that made by the colored light appears to be of the complementary color. The effect is due to the contrasts made by the shadows with the mixed light.

Color Table. A diagrammatic figure constructed to represent in graphic form the result of mixing primary colors. There are two such tables in general use, namely, Maxwell's and Newton's.

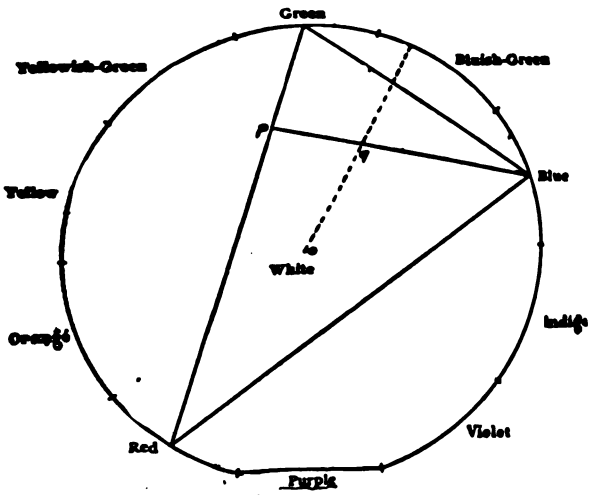


Maxwell's Color Table.

Maxwell's table is in the form of a rounded triangle. By mixing two colors on the same leg of the triangle a color is obtained of the same purity as the spectral colors; by combining those on opposite legs, we get a color mixed with white.

The angles of the triangle represent, respectively, red, green and blue.

Newton's table is a circle with a triangle contained in it, whose three angles also represent, respectively, red, green and blue. All the colors producible by mixing two colors are shown on a straight line joining the two, proportionately nearer to one



Newton's Color Table.

of the colors as that color dominates the mixture. Since white is at the center of the circle, any one of the colors can be joined to white and projected through the line of the red-green-blue triangle, thus indicating the formation of all existing hues.

Color, Unitary. A color in which it is impossible to detect any other color.

Commissure, Optic. The same as the Optic Chiasm, q. v.

Commotio Retinae. A functional disturbance of the retina due to violence, such as a blow on the head or eye.

Compound. In optics this term is applied to a reflecting or refracting system, made up of a series of lenses or mirrors, so placed in relation to each other that their resultant action may produce the required effect. All modern telescopes and microscopes are compound.

Compound Astigmatism is astigmatism in which both the chief meridians of the eye have their principal focal point either behind or in front of the retina. (See **Astigmatism.**)

Compound Lens. A lens containing both a sphere and a cylinder. (See **Lens.**)

Comus. A crescentic patch of yellow near the optic disc seen in high myopes. It is due to degenerated chorioid showing through the retina, caused by stretching of the chorioid.

Concave. Hollow and curved, as the inner surface of a sphere. Mathematically, a surface is concave when a straight line drawn from point to point falls between the surface and the eye. (See **Lens.**)

Concavo-Convex. Concave on one side and convex on the other. (See **Lens.**)

Concentric. Developed about a common center. Concentric lens surfaces in series exactly neutralize each other's refracting effects.

Concomitant. (Also written **Comitant.**) See **Strabismus.**

Condenser. A combination of two plano-convex lenses, with their convex surfaces in contact, for the purpose of gathering up aberrant and divergent rays of light and focussing them on a screen. Used in various kinds of image-making instruments. Also called a **Condensing Lens.**

Cone, Ocular. The cone of light formed within the eye by the rays entering the pupil and focussing on the retina.

Cone Test. See **Imbalance, Muscular.**

Conical Cornea. A bulging of the cornea forward in the shape of a cone, due to stretching. The cornea is always very thin and easily penetrated. Refraction, of course, is greatly distorted, for which there is no remedy except the pin-hole disc. The condition belongs to the eye-surgeon.

Conjugate Foci. Two points in a reflecting or refracting system so situated with relation to each other as to be optically inter-

changeable. Conjugate foci situated on secondary axes are called secondary conjugate foci.

Conjunctiva. The mucous membrane which lines the anterior surface of the eyeball and, being reflected, covers the inner aspects of the two eyelids. That which covers the eyeball is known as the bulbar, and that which lines the lids the palpebral, conjunctiva. The portion which lines the upper eyelid (conjunctiva tarsi) is adherent to the tarsus, and contains small glands, known as the glands of Krause. This portion derives its blood supply from two arterial arches, the superior and inferior tarsal arch. In the lower lid there is but one arch.

In the fornix, between lower and upper lid, the conjunctiva is extremely loose, so as to permit of free movements of the eyeball without hindrance from the lids.

The bulbar conjunctiva is continuous over the cornea, to which it is so closely adherent that it may be regarded as one of the layers of the cornea itself. Over the sclera (conjunctiva sclerae) it is attached by loose connective tissue, which is easily undermined so as to separate it from the sclera. There are no glands in the bulbar portion. The blood supply is derived from the posterior conjunctival and anterior ciliary arteries, which, at the corneal ring suddenly pass into the interior of the eye, but before doing so form loops for the nutriment of the cornea. There are, of course, no vessels in the transparent conjunctiva that covers the cornea.

Conjunctivitis.. Inflammation of the conjunctiva. There are countless varieties of this trouble, whose diagnosis must be left to the oculist. Some varieties are comparatively harmless, others exceedingly virulent. All present the ordinary signs of inflammation in the membrane, so that their presence is easy to recognize.

The chief diagnostic point in conjunctivitis is to distinguish it from keratitis and deep ciliary troubles. This is very readily done by noting the character of the injection of the vessels. In conjunctivitis this injection is superficial, brick-red in color, and diffused over the eyeball. The separate vessels are easily distinguished. (See **Keratitis.**)

Conjunctivoplasty. Plastic operation on the conjunctiva.

Consensual Reflex. A light reflex or accommodation in which one eye responds to stimulation of the other. See **Reflex.**

Conservation of Vision. See **Hygiene** and **Illumination.**

Contractor Pupillae. The sphinctre muscle of the iris which contracts the pupil.

Contra-Generic. Of opposite kinds. Applied to two surfaces of opposite curvatures in a compound lens.

Contra-Lateral. On opposite sides, as contra-lateral blindness.

Conus. See **Staphyloma, Posterior.**

Convergence. In optics in general, the term convergence is used to describe two lines which approach each other at a vanishing angle. In physiologic optics, the word is specifically employed to denote the turning of the eyes inward so as to converge the visual axes in order to achieve sigleness of binocular vision. For this it is necessary that light from identical points on the object shall fall upon the yellow spots of the two eyes simultaneously. For this, again, the visual axes must both be directed toward the point viewed.

If the object be situated at infinity, the visual axes must be practically parallel; and they are practically parallel, normally, when the eyes are in a condition of static balance. If, however, the object be situated at a point nearer than infinity, then, in order that the visual axes may meet at a point on the object, the eyes must be turned inward. This is accomplished by means of the internal rectus muscles, and is known as convergence. The external recti turn the eyes outward, restoring them to parallelism, this function being known as negative convergence.

The physiological aspects of convergence, and the nerve paths by which it is mediated, are discussed under the section devoted to **Physiology of Vision.** We shall here confine ourselves to a consideration of the mechanical and optical phases.

MATHEMATICS OF CONVERGENCE.

The mathematics of convergence is that of a triangle whose base is a straight line drawn between the centers of rotation

of the two eyeballs—or, for working purposes, between the two pupillary centers—and whose sides are the two converging visual axes. With a normal pair of eyes, under normal conditions, this triangle is an isosceles triangle, i. e., its two sides are equal and the two angles made by these sides with the base are equal, because the innervation of the two eyes is exactly equal and the degree of convergence made by the two visual axes similarly equal.

The angle made by the two visual axes with each other is known as the angle of convergence. It varies, in the same individual, inversely as the distance for which convergence is being made. At the far point, which in normality is at infinity, the angle is zero. At near point the angle is greatest. The actual size (in degrees) of the angle at any given point varies in different individuals according to the length of the base of the triangle, i. e., according to the pupillary width.

As many of the practical problems of convergence have to do with abnormal conditions, under which the two visual axes do not converge alike, this angle of convergence is not of much working value in dealing with such problems.

THE METER ANGLE.

More commonly employed as a unit of measurement is the angle made by each visual axis with a median line drawn perpendicularly from the middle of the base line. This angle, at 1 meter from the eyes, is called the meter angle, commonly designated as m. a. At other distances, nearer to and further from the eyes, it is a multiple or a dividend of the meter angle. Distance and meter angle vary inversely with each other; are, in fact, reciprocals of one another. At 50 centimeters the angle is equal to 2 meter angles; at 2 meters it is equal to .50 m. a.

The meter angle, as a unit of measurement for convergence, has two advantages: (1) It affords a separate angular unit for each eye's convergence, and (2) it coincides at all points with the unit of dioptric measurement of accommodation. At 1 meter, normal accommodation is 1 D., convergence 1 meter angle; at 50 cm., accommodation is 2 D., convergence 2 m. a.; at 2 meters, accommodation is .50 D., convergence .50 m. a. Nevertheless, the meter angle is not much employed in work-

ing out practical problems of convergence, even in association with accommodation problems.

THE PRISM DIOPTRE.

Much more generally utilized than either of the foregoing methods is the prism dioptre system of measuring convergence, which is, after all, the more practically useful, because most of our clinical testing of muscular conditions is done by means of prisms. The deviation made by the eye in convergence is regarded as the equivalent of the deviation given by a prism to a ray of light, and is measured in the same way —i. e., 1 cm. of deviation in 1 meter of distance constitutes 1 prism dioptre of convergence. The degree of convergence, in prism dioptres, is thus easily calculated for any point by dividing the distance (in meters) into the deviation made by the visual axis (in centimeters).

At infinity, of course, the deviation of the visual axis is nil; hence, also, the prism dioptrism of the convergence is zero. At any other distance the deviation is a constant quantity, namely, half the pupillary width, because the deviation is always to the median line. The distance for which convergence is made, therefore, (in meters), divided into half the pupillary width, gives the prism dioptres of convergence for that point.

As the meter angle is the reciprocal of the distance for which convergence is made, it is evident that multiplying the meter angle of convergence by half the pupillary width converts the meter angle measurement into prism dioptres. Further, as the average pupillary width is a trifle over 6 cm., the prism dioptres are a little over 3 times the meter angles for any given point of convergence. And, once more, as the meter angle coincides with the normal accommodation for any given point, it follows that the normal relation between convergence, in prism dioptres, and accommodation, in dioptres, is approximately as three to one.

AMPLITUDE OF CONVERGENCE.

The practical problems of convergence are rather different from those of accommodation. The mechanical conditions are also somewhat different. In the case of accommodation we are dealing with a single muscle (the ciliary) whose range of

function extends frankly from complete relaxation to maximal contraction. In convergence we are dealing, on the other hand, with a pair of muscles (the internal and external recti) whose functions oppose and counteract each other at every point.

The far point of accommodation denotes, and is physiologically determined by, the complete relaxation of the ciliary. For any point beyond that distance, i. e., for any light-waves of greater convergence, the eye has no way of adapting itself. In an emmetropic eye we say (although it is not quite true) that this far point is at infinity; that is to say, the light-waves to which it is adapted when the ciliary is completely relaxed are neutral waves; waves of any less curvature than neutral it has no way of focussing on its retina; therefore, for any point beyond infinity the emmetropic eye has blurred vision.

In the case of convergence we are confronted with a different situation. We say (although, again, not quite truthfully) that with both internal and external recti in a state of rest,—or, better, in static equilibrium—convergence in a normal pair of eyes is adapted for infinity, i. e., for parallel rays. But if a pencil of somewhat convergent waves be offered to the eyes, they still have a way of adapting themselves to them, by a little extra innervation of the externals, turning the eyes slightly outward,—known as negative convergence.

In determining the far point of convergence, therefore, it is necessary not only to find the far point of single binocular vision, but to demonstrate the far point at which both internals and externals are in a condition of static equilibrium.

DETERMINATION OF THE FAR POINT.

There are no objective methods of ascertaining the far point (or the near point) of convergence. Every test of the powers of convergence depends upon the patient's ability to maintain single vision. Fortunately, its subjective manifestation is a simpler and more definite affair than that of accommodation. If a patient can see singly a small object—a point of light at infinity or a black dot at near distance—then it is evident that he is maintaining convergence for that distance.

If, then, the patient sees a single image of a tiny round light 20 feet distant, we are sure that he is adapting his con-

vergence to infinity. The only question to be determined is whether this adaptation is, as it ought to be, a passive condition, in virtue of "letting go" all active innervation of both internal and external muscles, allowing the eyeball to assume a position of static equilibrium, or whether it is being maintained at the expense of some active muscular effort, on one side or the other, constituting a condition of unstable equilibrium.

The problem, then, resolves itself into one of determining the balance or imbalance of the two opposing sets of muscles when converging for infinity. If it be found that infinity is being fixed at the expense of some active effort on the part of the external muscles, then the patient's far point of positive convergence is really within infinity; for he is actually exercising negative convergence in order to see singly. If, on the other hand, we find that he is fixing infinity at the expense of active effort of his internals, then his far point of positive convergence is really beyond infinity, for he is exercising positive convergence in order to maintain single vision at infinity.

DISSOCIATING THE IMAGES.

As we have already explained in the section on Physiology, the maintenance of single binocular vision is incited by two stimuli, namely, the desire for a clear, single image of the object viewed, and the intuitive impulse to make convergence keep step with accommodation. At infinity the latter stimulus ought not to be operative. In an emmetrope it will not be. If it is present it can be eliminated by giving the patient full distance correction. The other factor,—the desire for a single image—can also be eliminated if we can deceive the patient into the belief that the images on the two retinae represent two different objects; he will no longer desire to fuse them.

This is known as "dissociating the images," and is accomplished by an optical trick which makes the two retinal images so dissimilar in shape, size, color, etc., that the patient no longer regards them as being images of the same object. He therefore makes no effort to fuse them, and allows his eyes to fall into their actual condition of static equilibrium. If the eyes were already in static equilibrium before the images were dissociated, then the two images remain fused anyway. If not,

as soon as the eyes, under the influence of dissociation, lapse into equilibrium, the two images separate—there is diplopia—and by the direction in which they separate we are able to judge which pair of muscles the patient was actively exerting before we tricked him into relaxing them.

MADDOX ROD.

There are several methods of effecting this dissociation. The most commonly used is the Maddox rod—a small cylinder of red (or white) glass set into an opaque disc. With this before one eye, and the other eye uncovered, the image of the test object (a small circle of white light) is drawn out by the rod into a streak of red light (at right angles to the rod) in one eye, while in the other eye it remains as a circle of white light. With no accommodation in force, and with no incentive to fuse the two dissimilar images, the eyes at once assume their position of real static equilibrium.

If the two images still remain fused—i. e., if the red streak and the white circle are seen in the same lateral plane—then the patient's eyes were in static equilibrium before we dissociated the images, and infinity is his far point of convergence.

If, on dissociation, the two images separate in the same direction as the eyes producing them, i. e., the red streak in the direction of the eye wearing the rod, the white circle in the direction of the uncovered eye—remembering that images are inverted in the eye, and seem to be, in space, on the opposite side to that which they occupy on the retina—we know that the eyes made a turn inward. Previous to dissociation, they were being held in fusion by an effort of the external muscles. The patient's real far point of convergence is inside of infinity.

If, on the other hand, upon dissociation, the images separate in the opposite direction, (crossed diplopia), then we know that the eyes have made a turn outward. They were previously held in fusion by an effort of the internals. The patient's real far point of convergence is beyond infinity.

ESTIMATING THE FAR POINT.

By applying the prism dioptre method of measurement, we can determine the precise amount that the eyes have turned, inward or outward, under dissociation. If they have turned

inward, we have only to find a prism which, placed before the eye with its base out, will bend the rays of light round its base just enough so that the eyes will see singly again; and that prism will represent the turn that the eyes made under dissociation, or, what is the same thing, the effort of the external muscles which they let go. If the eyes made a turn outward, we can discover the same thing by means of a prism placed before the eye base in.

According to the formula

$$\text{Prism dioptre} = \frac{\text{Deviation (in centimeters)}}{\text{Distance (in meters)}}$$

it is a simple matter to calculate from the finding where the patient's far point of convergence lies. If he proves to have made a turn of 6 prism dioptres inward, and his pupillary width is 6 cm., (half of this is the deviation), then distance will represent his far point:

$$\text{p. r.} = \frac{3}{6} = .50 \text{ cm.}$$

If the turn had been the same amount outward, then the result would be — .50 cm., or .50 cm. beyond infinity.

By the same token, the prism dioptres of convergence thus determined at the far point must be subtracted from the prism dioptres at near point of convergence in order to determine the amplitude of convergence. Thus, if the patient showed 6 prism dioptres at his far point, and 30 prism dioptres at his near point, his available amplitude is $30 - 6 = 24$ prism dioptres. If he showed —6 prism dioptres at his far point and 30 prism dioptres at his near point, then his amplitude is $30 - (-6)$, or $30 + 6 = 36$ prism dioptres.

THE NEAR POINT.

The determination of the near point of convergence does not involve any question of balance or imbalance between the internal and external muscles. It is true that the relation, normal or otherwise, between the two is a determining factor in the near point; but the near point contains and expresses this factor. Convergence at near point is always a condition of unstable equilibrium, in the sense that two antagonistic

muscles hold the eyes temporarily in a precarious poise, in virtue of a powerful fusion stimulus; and the near point represents the maximal net power of the internals in the struggle. We may, and doubtless shall, be interested in the question of balance at near point for other reasons, but not so far as the sheer ascertainment of the near point is concerned.

The near point of convergence, like its far point, is demonstrable only by subjective means. There is but one way to find it, and that is to see how close to the eyes a small light or black dot can be brought without the patient "seeing it double." All prism measurements of positive convergence err, because they eliminate the factor of accommodation, which is a legitimate and normal stimulus of convergence. To place before the eyes successively stronger prisms, base out, to discover the strongest prism power with which the patient can maintain single vision of an object at infinity, measures only convergence apart from accommodation; and such a test neither can nor does measure the normal amplitude of convergence. This form of muscle test has its value; but not for determining the near point or amplitude of convergence—for which the test must leave the interplay between accommodation and convergence unhindered.

The prism test just referred to is technically called the adduction test. It seldom develops more than 24 to 25 prism dioptres of power in the internal muscles. Natural convergence in a normal individual usually shows an amplitude of 30 to 32 prism dioptres.

ACCOMMODATION CONVERGENCE AND FUSION.

We have already noted that a certain ratio exists between the accommodation and convergence normally exercised for any given point, which, expressed in terms of meter angles and dioptres respectively, is a ratio of equality, and in terms of prism dioptres and lens dioptres is as 3 to 1. We have also recognized that accommodation is one of the factors in the stimulation of convergence.

All of the convergence exercised at a given point, however, is not the result of accommodation stimulus, but only about two-thirds of it. The ratio of this accommodative convergence to accommodation therefore, is about 2 to 1. The remaining

one-third is the result of direct stimulation by the fusion center. Fusion convergence is readily given up under dissociation of the images; accommodation convergence is not, so long as the demand for accommodation remains.

RELATIVE CONVERGENCE.

As with accommodation, so with convergence, a certain amount can be forced into action after near point has been reached by means ot prisms, base out, and a certain amount can be suppressed by means of prisms, base in, without impairing the singleness of the image. This is known as relative convergence.

NEGATIVE CONVERGENCE.

The office of the external recti is to undo the work of the internals, and to restore the eyes to parallelism. The power of the externals, therefore, in this respect, is precisely equal to that of the internals. Further than this the externals cannot normally be made to act. By means of prisms, however, base in, we can force them into action to pull the eyes outward from the median line, to the extent, in normal eyes, of some 8 to 10 prism dioptres. This action is also spoken of by many authors as negative convergence, but is perhaps better termed abduction, since it has nothing whatever to do with convergence.

There is no basis of comparison between this abduction and the amplitude of convergence, since the latter is a normal physiological function, while the former is a forced, artificial feat. It can however fitly be compared with the power of adduction, to which it stands normally in the ratio of 1 to 3. Indeed, the principal value of these two tests—adduction and abduction—is to ascertain the state of this relationship. Absolute shortages of power, of equal amounts, in the two sets of muscles, are not, as a rule, of serious import. A marked disturbance of the 3 to 1 ratio between them usually indicates some physical trouble with the muscle that falls short of its quota.

ACCOMMODATIVE EXOPHORIA.

When the internal muscles contract to pull the eyes inward in the act of accommodation, a potential recoil is developed in the externals of precisely the same amount (a) to hold the

eyes fixed at the point accommodated and converged for, and (b) to restore the eyes to parallelism as soon as the tension in the internals shall be released. Thus, with every exercise of convergence an amount of outward imbalance is created, equal to the amount of convergence used.

At a near point, say of 25 cm., for example, about 12 prism dioptres of convergence is exercised, antagonized by a counter-recoil of 12 prism dioptres in the externals. About two-thirds of this 12 dioptres of convergence is maintained by the stimulus of accommodation; the rest is held in virtue of stimulation from the fusion center. In other words, 8 dioptres is accommodation convergence, 4 dioptres fusion convergence. If, therefore, we can dissociate the images, and destroy the fusion stimulus, we shall induce the patient to give up 4 dioptres of his convergence.

This dissociation is very easily accomplished. For a test chart we use a black horizontal line, from the middle of which rises a perpendicular index pointer, some half an inch in height. On either side of the index pointer the line is graded into centimeters. We place before the right eye a 5 or 6 dioptre prism, base up. This immediately produces two images of the line, the false image seen by the right eye being about half an inch below the real image seen by the left eye. The images being thus dissociated, the fusion stimulus, in a few moments, ceases to act, the eyes give up the 4 dioptres of convergence due to that stimulus, and make a turn outward of that amount. This is evidenced by the lower line on the chart shifting to the opposite side, so that the index pointer, instead of standing immediately under the pointer of the upper line, stands under the 1 cm. mark on the left hand side.

Applying our formula,

$$\text{Prism dioptre} = \frac{\text{Deviation (in centimeters)}}{\text{Distance (in meters)}}$$

we have the following:

$$\text{Prism dioptre} = \frac{1}{.25} = 4 \text{ p. d.}$$

showing that we have 4 prism dioptres of outward turn, mean-

ing that the eyes have surrendered 4 dioptres of convergence because of the removal of the fusion stimulus.

This amount of imbalance, which is thus manifested at the near point by dissociation of the images, is known as accommodative exophoria. In normal eyes it is a fairly constant quantity—about one-third of the calculated convergence. In ametropia it varies, according to the degree of accommodation employed; and the nature and extent of the variation affords us valuable data in our investigation of the refraction of the eyes.

Thus, a hyperope of, let us say, 2 D., for 25 cm. uses 6 D. of accommodation instead of 4 D. At the established ratio, he develops twice this number of prism dioptres of accommodation convergence, or 12 prism dioptres. That is to say, all his convergence at this point is accommodation convergence; hence he will not be likely to yield any of it under the dissociation test. A myope of 2 D., on the other hand, uses only 2 D. accommodation at this distance, and develops only 4 prism dioptres of accommodation convergence. The rest of the 12 prism dioptres employed—8 p. d.—must be stimulated by the fusion center; hence, under the dissociation test at near point this myope will probably give up some 8 prism dioptres of his convergence, or, in other words, will show 8 prism dioptres of accommodative exophoria.

It must not be supposed, however, that variations in accommodative exophoria always work out with this regularity in their relation to errors of refraction. Indeed, hyperopes occasionally exhibit undue exophoria at near point. Physical defects in the muscle not infrequently cause variations.

EXOPHORIA IN ACCOMMODATIVE INSUFFICIENCY.

Presbyopes naturally exhibit large degrees of accommodative exophoria, because at near points of 33 to 25 cm. they exercise no accommodation at all. Their entire convergence is achieved in virtue of the fusion center stimulation.

By the same token, young patients who suffer from accommodative insufficiency are obliged to supplement their accommodative stimulus with an extra powerful effort of the fusion center in order to maintain proper convergence at near point;

and they yield correspondingly larger amounts of exophoria under dissociation than do normal persons.

Eberhardt, indeed, makes this a standard test of the sufficiency of the accommodation for reading purposes. If the accommodative exophoria is abnormal, he adds plus lens power until it becomes normal, and prescribes that plus power for reading.

Convergent Strabismus. Strabismus in which the visual axes are inclined toward each other. See **Strabismus.**

Convex. Curved with a rounded elevated surface, like the outside of a sphere. Mathematically a surface is convex when, if a straight line be drawn from point to point, the surface lies between the line and the observer.

Convexo-Concave. Applied to a lens which is convex on one side and concave on the other, the convex curvature predominating. See **Meniscus** and **Lens.**

Coordinate. As a verb the word signifies to put into action a pair or a group of muscles, directed to some single, purposeful end. As an adjective, it describes such a group-action.

As applied to the muscles of the eye, it is usually employed to indicate the use of the muscles in homonymous pairs, as distinct from their conjugate use.

Copiopia. Fatigue of the eye from long or improper use.

Copopsia. Same as **Copiopia.**

Coquilles. Shell-shaped glasses, usually tinted, for protection of the eyes. Green states that in order that the lenses may have a zero of refracting power the concave surface should be of less curvature than the convex, the difference between the radii of curvature being one-third the thickness of the glass at its thickest point.

Corectasis. Dilation of the pupil.

Corectome. An instrument for cutting the iris.

Corectopia. Displaced pupil.

Coredialysis. Detachment of the iris from the ciliary body for the purpose of making an artificial pupil.

Corelysis. Detachment of the iris from the cornea or the crystalline lens, to which it has become adhered.

Coremorphosis. Making an artificial pupil.

Cornea. The transparent membrane set into the front part of the sclera, somewhat like a crystal into a watch, forming the front window of the interior chamber. It is the first refracting medium through which the light passes on entering the eye. It consists of five layers, from without in, as follows:

Epithelium
Bowman's Membrane
Cornea Proper
Descemet's Membrane
Endothelium

The cornea has no blood vessels, as these would interfere with its transparency, but is richly furnished with nerves in Bowman's membrane. The epithelial layer (sometimes called the conjunctiva of the cornea) protects these nerves. The cornea proper is composed of a horny, transparent, non-sensitive substance, which serves to give shape and support. Descemet's membrane and the endothelium protect the cornea from within. The epithelium readily regenerates itself after injury; but Bowman's membrane, once destroyed, never reproduces itself.

Optically, the cornea has a convex curvature anteriorly and a concave surface posteriorly. Its index of refraction varies, being greatest in the cornea proper. The average index is 1.333. The curvature also varies somewhat in different individuals, and is not the same in all meridians. The average radius of the anterior surface curvature is 12 mm. in the horizontal meridian and 11 mm. in the vertical, thus being slightly more convex in the latter, and producing a slight astigmatism, which, however, is negligible. The average radius of curvature of the posterior surface is 7.5 mm. The cornea therefore has the effect of a periscopic convex lens (See **Lens**), which, calculating its curvatures and its index of refraction, exerts a refracting power of about 43 dioptres. Immediately behind the cornea is the aqueous humor, with an index

of 1.336, so that the refraction of light passing from the cornea to the humor is practically nil.

Cornea, Decentration Of. A condition of the cornea in which the geometric centre and the optical centre do not coincide. It is one of the causes of vertical heterotropia.

Cornea, Ectasia Of. Bulging of the cornea. Anterior staphyloma.

Corneal Astigmatism. See **Astigmatism.**

Corneal Facets. Small flat areas of surface on the cornea, usually due to injuries or chronic ulcers.

Corneal Reflex. Winking of the eye when the cornea is touched.

Corpora Quadrigemina. See above. These bodies are four in number, as their name implies.

Corporata Geniculata. Two important ganglia in the mid-brain which, together with the quadrigeminal bodies and the optic thalamus, constitute the first relay station in the transmission of the visual impulse from the retinae along the optic tract.

Corpuscular Light Theory. The theory held by Newton that light consisted of minute corpuscles of matter which bombarded the retina. See **Light.**

Corpus Vitreum. The vitreous body.

Correction. In optics this term is applied to the lens power, or combination of lens power, which, placed before the ametropic eye, renders it emmetropic.

Corresponding Points of the Retinae. Coincident points in the two retinae, i. e. at the same relative distances and positions from the visual centres, upon which light waves from identical points of an object fall, producing single vision. (See **Binocular Vision**). They are also called identical points of the retinae.

Cortical. The cortex of an organ is the part that lies nearest to the outer border; the opposite of the nucleus. Anything,

therefore, is cortical which pertains to the outer border of an organ, as a cortical cataract, involving the circumferential portion of the lens.

Coruscation. A sensation of a flash of light before the eyes.

Couching. Operation by which the lens is displaced out of the line of vision by use of the couching needle.

Cover Test. A test for muscular imbalance, made by covering the sound eye suddenly while both eyes are fixing a point. If there is no imbalance, the uncovered eye will remain stationary; if there is imbalance, it will make a slight turn, so as to get a new fixation status.

Crisis, Ocular. Severe pain in the eyes and brow sometimes occurring in locomotor ataxia.

Critical Angle. See **Angle.**

Crossed Cylinders. Two cylindrical lenses placed in apposition with their axes at right angles to each other. Two equal and similar cylinders thus placed would, of course, make the optical equivalent of a spherical lens. The term, as generally used, therefore, usually implies cylinders of unequal power or unlike curvature.

The use of cross-cylinders, as originated by Jackson, for the testing of presbyopia, and later by Lockwood, for finding the comfortable near-point, will be found described in detail under the heading of **Accommodation.**

Crossed Diplopia. Diplopia in which the image in the deviating eye is projected to the opposite visual field. See **Diplopia.**

Cross-Eyed. Having a strabismus.

Crossed Eyes. A common term for strabismus.

Cross-Hair. A thin thread or wire stretched across the focal plane of an optical instrument for purposes of localization. Two such strands are often stretched at right angles to each other, in order to localize a point where they intersect.

Crossed Lens. A lens which shows the minimum of aberration for neutral waves. Such a lens is a bi-convex or a bi-concave whose front surface has a curvature six times as great as that of its back surface. The plano-convex is almost as good. The crossed lens, when made of flint glass of 1.6 index, is a plano-convex.

Cross, Maddox. A cross device designed by Ernest Maddox, the vertical and horizontal arms being graduated in centimeters, for measuring vertical and lateral heterophoria and squint.

Cross-Section. A section made at right angles to the principal axis.

Cryptophthalmia. A congenital malformation, consisting of adhesion of the lids to the eyeballs, or of the lids to each other.

Crystalline Lens. (See **Lens, Crystalline**).

Cul-De-Sac. A blind pouch. There are many cul-de-sacs in human anatomy. In ophthalmology the term is applied to the sac formed by the bulbar and the palpebral conjunctiva.

Cupped Disc. A depression or excavation of the optic disc, apparent with the ophthalmoscope by reason of the fact that the edge and centre of the disc cannot be focussed simultaneously. There are three varieties:

Physiologic, due to the separation of the optic nerve fibres behind the retina instead of in the same plane. It is never complete, and the lamina cribrosa is in normal position. The rest of the eye-ground is normal.

Atrophic, caused by disappearance of the nerve fibres. Excavation is total but shallow, the lamina cribrosa is in place and the area is white. (See **Optic Atrophy**).

Glaucomatous, originating in the recession of the lamina cribrosa, due to intraocular tension. The excavation is total and deep, as shown by the bending of the vessels as they emerge from the cup. In early stages the nerve head is still pink, but later becomes pale. There are other signs of glaucoma (q. v.).

Curtometer. An instrument for measuring curved surfaces.

Curvature. The gradual bending of a surface without making an angle. It is the uniform curvature of a refracting surface which enables it to bring light to a focus at one point. Other things being equal, the greater the degree of curvature, the greater the refracting power. Degree of curvature is expressed in two ways, (1) in terms of the meter curve, i. e. the degree of curvature of a sphere whose radius is 1 meter, and (2) in terms of the radius of the curve.

Cyanopsia. A condition in which everything is seen blue.

Cyclitis. Inflammation of the ciliary body of the eye. A very serious condition, which almost always involves the entire internal structure of the eye, giving great pain, dimness of vision, and cloudy media. Light is painful because it causes the ciliary muscle to contract. As the chorioid, the iris, and ciliary are all parts of the same tissue-system, inflammation of one is frequently accompanied by inflammation of the other two.

Cyclodialysis. An operation for detachment of the ciliary body at its periphery.

Cyclophorometer. An instrument for measuring cyclophoria. The most generally used consists of two metal disks, connected by a rigid bar, with a Maddox rod in the centre of each, which can be rotated to any desired angle.

Cyclopia. A single eye in the middle of the forehead.

Cyclophoria. Imbalance of the extrinsic muscles of the eye in which the oblique muscles play a dominant role, causing the eye to deviate, under test, obliquely. (See **Heterophoria**).

Cycloplegia. Paralysis of the ciliary muscle, so that the pupil is dilated and accommodation is suspended. This condition is frequently brought about artificially, by means of a drug, either to procure rest for the muscle in inflammation, or to enable the refraction of the eye to be measured without any accommodation in force. The drug most commonly used in the first class of cases is atropine; in the second class, homatropine; the former drug being profound and lasting in effect, the

latter light and transient. Cocaine is also a cycloplegic, but is not used for that purpose.

Cycloplegic. A drug which paralyzes the ciliary muscle. (See above).

Cylinder. This geometric figure is difficult to define mathematically. It is a long, round solid body, terminating at each end in a flat, circular surface, these two surfaces being parallel to each other. In right cylinders the straight line joining the centres of the two bases is perpendicular to the bases, in oblique cylinders, it makes an acute angle with them.

Optically, the importance of a cylinder is that its surface presents a uniform crescendo of refracting power, from the minimum, along its cylinder axis (see **Axis**), to the maximum, at right angles to its cylinder axis. The minimum power is always zero, since it has no curvature parallel with its axis; the maximum power depends upon the radius of the circular aspect. Intermediate refracting power is in direct proportion to the angular distance of the meridian in question from the axis. Thus, at 30 deg. from the axis, which is one-third of ninety deg., the cylinder has one-third of its maximum power; at 45 deg. one-half, etc.

Another peculiar property of a cylinder is that, so far as refraction is concerned, it represents the split half of a sphere. Thus, if two cylinders, of equal radius, be placed in apposition with their axes at right angles to each other, every meridian is so reinforced by the combination as to give to every meridian the maximum refracting power of either cylinder, thus giving to the combination the refracting value of a sphere. This gives a cylindrical lens, (made of a segment of a cylinder), the power of correcting regular astigmatism. (See **Astigmatism** and **Lens**).

Dacryadenalgia. Pain in the lacrymal gland.

Dacryagogatresia. Closure of a lacrymal duct.

Dacryagogue. A medicine which promotes the flow of tears.

Dacryma. A tear.

Dacryoadenitis. Inflammation of the lacrymal gland.

Dacryocele. A cyst of the lacrymal sac.

Dacryocyst. See above.

Dacryocystalgia. Pain in the lacrymal sac.

Dacryoma. A tumor of the lacrymal organs.

Dacryon. The lacrymal point.

Dacryops. Distention of the lacrymal sac.

Dacryopyorrhea. A flow of pus from the lacrymal sac.

Dacryopyosis. A mixture of tears and pus.

Dacrycystitis. Inflammation of the tear duct, which may become infected either from the conjunctiva or from the nose. There is usually stoppage of the duct, so that the tears overflow the eye, the serum or pus exudes from the duct itself.

Daltonism. Another name for color blindness, so called because Dalton first demonstrated it.

Darkness Acuity. The acuity of vision in comparative darkness or low degrees of light.

Day-Blindness. A condition in which vision is better at night than in the day-time. It may be due to a retinal trouble, in which the bright light of day impairs function, or to a central opacity of the lens, so that when the pupil dilates under the influence of dusk an aperture is made around the opacity for the entrance of light.

Decentration. A lens is said to be centered when its optical centre coincides with the visual axis of the eye; and as the visual axis of the eye in a state of rest is supposed to pass through the geometrical centre of the lens, a lens is regarded as being centered when its geometrical and its optical centres coincide. When this is not the case, i. e. when the optical centre is to one side or other of the geometrical centre, the lens is said to be decentered. When the optical centre is to

the inner side of the geometrical, it is said to be "decentered in"; when the reverse, it is "decentered out."

PRISM EFFECT OF DECENTERING.

It can be readily seen that the effect of a spherical lens which has been decentered is that of a prism before the eye, because at any point in a spherical lens other than its optical centre the plans of the two surfaces are not parallel, but are inclined to each other at an angle depending upon the degree of curvature. When, therefore, the visual axis passes through a lens at any other point than the optical centre the effect is the same as looking through a prism. Whether the prism be base in or out, up or down, depends upon whether the sphere is a convex or a concave one, and upon the direction of displacement.

Since a convex lens is thickest at its optical centre, the base of the prism produced by its decentering always is toward the optical centre of the lens; hence when a convex lens is decentered, the base of the prism is in the same direction as the decentering. A concave lens being thinnest at its optical centre, the prism produced by its decentering has always its base away from the optical centre; hence when a concave lens is decentered the base of the prism is in the opposite direction of the decentering.

As a decentered spherical lens has the double effect of a spherical lens of the strength indicated, plus a prism of the character and strength corresponding to the degree of decentration, and as it is often desirable to combine a prism with a sphere, lenses are often prescribed to be decentered so as to give the required prism effect.

AMOUNT OF PRISM EFFECT PRODUCED.

The stronger the lens, of course, the smaller the degree of decentration needed to produce a given prism effect. Approximately 1 prism dioptre is produced by decentering a 1 D. lens 1 cm. Hence, in determining the amount of decentration necessary to produce a given number of prism dioptres with a lens of a given strength, we simply divide the number of prism dioptres desired by the dioptrism of the lens, and the quotient is the number or the fraction of the centimeters of

decentration necessary. For instance, if it is desired to produce 2 prism dioptres with a 4 D. lens, we divide 4 into 2, which gives 0.5; the necessary decentration is 0.5 cm., or 5 mm.

Following is a table of the amount of prism power obtained by decentering spherical lenses for each dioptre of lens power. The same table holds good for decentering cylindrical lenses provided the decentering be done in a direction at right angles to the axis of the cylinder; if the cylinder be decentered in any other direction its prism effect must be calculated according to the meridian along which the decentration takes place. Decentration along the axis, of course, produces no prism effect, as there is no lens power in that direction.

Prism Dioptres Produced by Decentration Per Millimeter.

Diopt.	1m/m	2m/m	3m/m	4m/m	5m/m	6m/m	7m/m	8m/m	9m/m	10m/m
0.25	.025	.050	.075	1.00	.125	.150	.175	.200	.225	2.50
0.50	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50
0.75	.075	.15	.225	.30	.375	.45	.525	.60	.675	.75
1.00	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00
1.25	.125	.25	.375	.50	.625	.75	.875	1.00	1.125	1.25
1.50	.15	.30	.45	.60	.75	.90	1.05	1.20	1.35	1.50
1.75	.175	.35	.525	.70	.875	1.05	1.225	1.40	1.575	1.75
2.00	.20	.40	.60	.80	1.00	1.20	1.40	1.60	1.80	2.00
2.25	.225	.45	.675	.90	1.125	1.35	1.575	1.80	2.025	2.25
2.50	.25	.50	.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
2.75	.275	.55	.825	1.10	1.375	1.65	1.925	2.20	2.475	2.75
3.00	.30	.60	.90	1.20	1.50	1.80	2.10	2.40	2.70	3.00
3.25	.325	.65	.975	1.30	1.625	1.95	2.275	2.60	2.925	3.25
3.50	.350	.70	1.05	1.40	1.75	2.10	2.45	2.80	3.15	3.50
3.75	.375	.75	1.125	1.50	1.875	2.25	2.625	3.00	3.375	3.75
4.00	.40	.80	1.20	1.60	2.00	2.40	2.80	3.20	3.60	4.00
4.25	.425	.85	1.275	1.70	2.125	2.55	2.975	3.40	3.825	4.25
4.50	.45	.90	1.35	1.80	2.25	2.70	3.15	3.60	4.05	4.50
4.75	.475	.95	1.425	1.90	2.375	2.85	3.325	3.80	4.275	4.75
5.00	.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00
5.25	.525	1.05	1.575	2.10	2.625	3.15	3.675	4.20	4.725	5.25
5.50	.55	1.10	1.65	2.20	2.75	3.30	3.85	4.40	4.95	5.50
5.75	.575	1.15	1.725	2.30	2.875	3.45	4.025	4.60	5.175	5.75
6.00	.60	1.20	1.80	2.40	3.00	3.60	4.20	4.80	5.40	6.00

When it is desired to decentre a lens both horizontally and vertically at the same time, the effect can be obtained by performing a resultant decentration in an oblique direction between the horizontal and the vertical. For such a resultant decentration the amount of prism power required is found by adding together the squares of the horizontal and vertical prisms and extracting the square root of the sum, and the position of the base of the resultant prism is determined according to the following formula:

$$\frac{\text{Horizontal prism X 90}}{\text{Total prism}} = \text{degrees from the vertical.}$$

(In the foregoing formula the expression "total prism" refers to the sum of the prism power in the horizontal meridian and that in the vertical meridian.)

Decimeter. One-tenth of a meter. About 4 inches.

Declination. This term is applied to the deviation of the vertical axis of the eyeball when the latter turns on its antero-posterior axis. Such action is, of course, due to the action of the oblique muscles. When the upper end of the vertical axis inclines toward the nose, it is called positive declination; when toward the temples, negative declination.

Decomposition. As applied to light, the word signifies the breaking up of the white pencil of light into its constituent color waves, either by means of a prism or by diffraction. (See **Prism** and **Diffraction**).

Decussation. A crossing or intersection of lines or paths. Rays of light decussate at the point of reversal; but as rays are only geometrical lines, used to illustrate the direction of light-waves, we cannot properly say that light decussates. The term, in fact, does not technically belong to optics, but to physiology, where it is applied to the crossing or intersection of nerve fibres. There is a partial decussation of the fibres of the optic tract at the chiasm, q. v.

Density, Optical. The property possessed by bodies or substances of retarding the velocity of light waves.

Dennett's Prism Nomenclature. The system of measuring prism deviation in angles consisting of a hundredth of a radian. See **Prism.**

Dental Amblyopia. Amblyopia due to diseases of the teeth.

Deorsumvergence. Turning of the eyes downward.

Depilation. Removal of hair.

Depth. In optics this term denotes the quality of solidity, as perceived by the vision. See **Binocular Vision.**

Deplumation. Loss of eyelashes.

Deprimens Oculi. Another name for the inferior rectus macula.

Descemetitis. Inflammation of the Descemet's membrane.

Descemet's Membrane. The fourth layer of the cornea, which lies immediately behind the cornea proper. Also called the internal limiting membrane. (See **Cornea**).

Deviation. Literally, turning aside. Used in optics to denote (1) the bending of the path of a light wave from its original course by the action of a prism, and (2) the turning of the visual axis in or out from the median line in convergence. (See **Prism** and **Convergence**). In the former case, deviation (in centimeters) is equal to the distance from the prism (in meters) at which the calculation is made, multiplied by the dioptric power of the prism. Thus. a 2 dioptre prism gives a deviation of 6 centimeters at 3 meters distance from the prism. Or deviation may be measured in terms of the angle of deviation, or by the sine of that angle.

Primary and secondary deviation are terms used in connection with strabismus. Primary deviation is the deviation made by the strabismic eye when the sound one is fixing. Secondary deviation is the deviation made by the sound eye when the bad one is fixing.

Conjugate deviation is the turning of both eyes at once in the same direction, as when we turn them to look to right or left. In certain diseases of the brain there is constant, involuntary conjugate deviation.

Deviometer. An instrument for measuring the deviation of the eye in strabismus. See **Strabismus.**

Dextrocular. Right-eyed, i. e. having the right eye the dominant eye.

Dextroduction. Movement towards the right of the visual axis.

Dextrophoria. A condition of conjugate imbalance, in which the two eyes tend to turn to the right.

Diacaustics. See **Caustic.**

Diameter. A straight line joining two opposite points on the circumference of a sphere or circle, passing through the centre.

Diaphanometer. An instrument for estimating the amount of solids in a fluid by measuring its transparency.

Diaphonoscope. Diaphonoscopy. An instrument and method of examinating tissues by transillumination.

Diaphragm. A muscular or membranous curtain, dividing two open spaces or chambers. In the eye, the iris fulfills this description.

Diapyesis. Suppuration.

Dichromate. A color-blind person who can distinguish but two colors, usually complementary colors.

Dichromatic. Seeing two colors at one time.

Dichromatism. If white light is allowed to fall upon certain colored solutions, the transmitted light is of one color when the thickness of the solution is small, and quite another color when the thickness is great. Thus, if a beam of white light be projected through a solution of chlorophyll, if the thickness of the solution be not great it is seen on the other side as green; but if the thickness of the solution be considerable, then it appears on the other side as quite a deep red. The explanation is as follows: The solution is moderately transparent for a large number of rays in the spectral neighborhood of green, and for only a few red. The small amount of red is at first overpowered by the large amount of green, but, having a smaller coefficient of absorption, it finally becomes predominant if it travels through a sufficient thickness. This phenomenon is known as dichromatism.

Diffraction. A term applied to the modification which rays of light undergo when they pass over the edge of an opaque body. Thus, when a beam of light is admitted into a dark chamber through a narrow slit, and falls upon a screen, there appears a line of white light bordered by a fringe of alternate

colored light and dark; this fringe is produced by the decomposition of the light by the edge of the substance through which it passes, and is known as diffraction bands.

The original light waves are known as primary, and the waves resulting from the diffraction, secondary waves. It appears that the secondary waves possess similar properties to the extraordinarily refracted waves of double-refracting crystals, i. e. they are polarized. By means of millions of tiny perforated lines in an opaque diaphragm, placed exceedingly close together, light may be thus thoroughly decomposed. Such a device is known as a "grating," and practically the entire light that passes through the grating is polarized. (See **Polarization**).

Diffraction of light gives rise to many of the most abstruse and complicated problems in optics.

Diffusion. A gradual and thorough dispersion of light among the particles of some absorbing or transparent medium. The light of the sun is thus diffused, normally, through the air. By this means a very uniform illumination is obtained, and modern artificial lighting aims to imitate it. Diffused light must be re-polarized and re-focalized before it can produce an image.

Diffusion Circle. Circles of light presented by spherical waves of light at any place in their course other than their focal point. These circles of diffusion fall on the retina, instead of focal points, in ametropia.

Geo. A. Rogers points out that the diffusion circles which fall on the retina in hyperopia and those in myopia are not alike, since the former consist of diminishing (minus) waves, whose peripheries strike the retina first, while the former consist of expanding (plus) waves, whose apices strike first; this, however, can hardly have any practical significance.

Dilatation. Expansion. Applied to a hollow vessel or organ. When an aperture is in question, we use the term **Dilation,** as of the pupil.

Dilator. This word has two applications in physiology. First, it is applied to a muscle, or set of muscles, which bring about

a dilatation of the organ or aperture which they supply; thus, the radiating muscles of the iris are called irido-dilators. Second, it is applied to a drug or other agent which causes dilatation, e. g. atropine, cocaine, etc.

Dilator Iridis. The radiating muscle which dilates the pupil.

Dionin. A derivative of opium which, in a 1 per cent to 5 per cent solution is used in the eye to promote glandular activity. It is useful in incipient cataract, iritis, cyclitis, etc.

Dioptometer. Dioptrometer. An instrument for measuring refraction.

Dioptometry. Dioptrometry. Measurement of the refraction of the eye.

Dioptre. The unit of focalizing power. One dioptre is the power to focalize a neutral wave of light at a distance of 1 meter. (See **Lens**).

Dioptrics. The science of light refraction.

Dioptroscopy. Measurement of refraction by means of the ophthalmoscope.

Diplocoria. A double pupil in the eye.

Diplomometer. An instrument for measuring diplopia.

Diplopia. Double vision, due to the fact that the central rays of light from the object do not fall coincidently on the yellow spots of the two retinae. In the outer, peripheral areas of the visual field there is always double vision, as the rays from these areas never fall on identical retinal points. This, however, does not concern the individual, provided the central parts of the image coincide. Only when the central images are out of coincidence does he complain of diplopia.

Diplopia is said to be homonymous when the two images appear to be on the same sides, respectively, as the eyes which see them; heteronymous when they appear to be on opposite sides; the latter is also called crossed diplopia. The image seen by the fixing eye is termed the true image; that which is

seen by the deviating eye, the false image. It is to be remembered that the apparent displacement of the false image is always in the opposite direction to that in which the eye deviates. Vertical displacement occurs when the visual axes are not parallel, or when the eyes stand at different levels.

When one or both eyes are twisted on the saggital axis, the upper or lower extremities of an object may approximate, so that the image takes the form of an upright or inverted V.

Since diplopia is the subjective manifestation of heterotropia, or strabismus, its diagnosis, measurement, and general management are, of course, those of strabismus, q. v. It may be either paralytic or functional. Below will be found a table showing the displacement of the image and the behavior of the diplopia in the disablement of the various ocular muscles. The table is meant to apply to paralytic diplopia, but it holds good in general for functional diplopia, except that in the functional cases there is no increase of diplopia upon making conjugate movements:

Key to table.

DH	Homonymous diplopia
BX	Crossed diplopia
DR	Right vertical diplopia
DL	Left vertical diplopia
Er	Eyes right
El	Eyes left
Eu	Eyes up
Ed	Eyes down

inc. denotes increased

R. external rectus	DH inc. in Er
L. internal rectus	DX inc. in Er
R. internal rectus	DX inc. in El
L. external rectus	DH inc. in El
R. superior rectus	DL inc. in Eu and r.
L. inferior oblique	DR inc in Eu and r.
R. inferior oblique	DL inc. in Eu and l.
L. superior rectus	DR inc. in Eu and l.
R. inferior rectus	DR inc. in Ed and r.
L. superior oblique	DL inc. in Ed and r.
R. superior oblique	DR inc. in Ed and l.
L. inferior rectus	DL inc. in Ed and l.

For further discussion of this subject the reader is referred to the section on **Strabismus.**

Diplopia, Physiologic. Double vision which normally occurs of

those portions of the visual field which are outside the horopter. See **Binocular Vision.**

Diploscope. An instrument devised by Remy for the determination of binocular vision and detecting malingering, based upon the bar-reading principle of Javal. It consists, essentially, of two tubes, with a broad bar across them, through which the patient reads a distance type chart.

Direct Image. Image of the fundus seen by the direct method of ophthalmoscopy.

Direct Method. See **Ophthalmoscopy.**

Direct Vision. Vision in which the focussed light waves fall upon the macula.

Discission. Needling the capsule of the crystalline lens in soft cataract.

Discoria. Same as Diplocoria.

Disc, Optic. A white, circular area seen with the ophthalmoscope on the retina, about 1.5 mm. in diameter, a little to the nasal side. It represents the place where the optic nerve enters the eye, and is itself impervious to light stimulation; whence it is also known as the blind spot. It is slightly raised from the level of the retina.

The disc is one of the chief landmarks and points of interest in an ophthalmoscopic examination of the eye. In order to view it, the light must be thrown into the eye slightly to the temporal side of the cornea. In health it appears a light pink, tinged with yellow, of a lustrous texture. Around its circular edge can be seen the blood vessels which enter the eye along with the nerve to spread themselves over the retinal field. In inflammatory conditions of the brain, and intracranial tension, the disc is crowded with engorged vessels around its edge, which are raised above the level of the nerve-head—a condition known as choked disc. In optic atrophy, on the contrary, the nerve substance wastes away, showing a depression in the disc and the lamina cribrosa is plainly seen. In optic neuritis the disc is reddened and the vessels enlarged. In glaucoma the depression is exaggerated into a cup, (See

Cupped Disc) and the surrounding vessels are bent as they emerge. Thus many important diseased conditions are made manifest in the appearance of the optic disc.

Optically the disc has little value. It is possible, by means of the ophthalmoscope, using the disc as an objective, to estimate the refraction of the eye; but nobody would ever think of utilizing so difficult and faulty a method. (See **Ophthalmoscope**). The fact that the disc is impervious to light stimulation makes it a convenient spot upon which to focus the light of the retinoscope, ophthalmoscope, and other brightly illuminated instruments. We also use the diameter of the disc as a rough standard of measurement for other areas of the retina, saying "about two discs from the macula," etc.

Discs, Mason's Pupil. Opaque discs, with cental aperture, of various sizes, for the purpose of measuring the size of the pupil at rest and in varying degrees of accommodation.

Discs, Volkmann's. A device for determining the angular relation of the vertical meridians of the eyes. Two revolving discs, each containing a single radius, are pinned on the wall, separated by the pupillary width, and viewed steroscopically. The discs are then turned until the two radii form one continuous straight line.

Discs, Walker's Color. Two discs. of different color, affixed one to each end of a rod, but with their planes at right angles to each other, so that it is impossible to see both colors at once. Used as color tests.

Disparate Points. Objectively this term denotes two points, one in each retina, upon which light falling from the same point of an object produces a double image. Subjectively, it is used to denote the two points in space where these two images appear to be situated. The apparent separation of the two images in diplopia is called their disparation.

Dispersing Lens. A lens which causes light waves to expand, and thus to travel away from their centre, i. e. a concave lens.

Dispersion. A term applied to the angular separation of the component rays of a pencil of light on emerging from a refract-

ing medium whose surfaces are not parallel to each other, e. g. a common prism. The length to which they are drawn out varies, of course, with the refracting index and surface-inclination of the dispersing medium. (See **Prism**).

Displaced Macula. A macula which does not occupy the position of visual centration in the retina. It is a congenital condition, and one of the frequent causes of vertical heterotropia.

Distance. The measurements of space between two objects. In optics the word usually applies to the space between two fixed mathematical points.

Focal Distance. The distance between the optical centre of a lens or mirror and its principal focal point.

Infinite Distance. Optically, this denotes the distance in which waves of light, originating at a luminous point, are rendered neutral or parallel. Actually, of course, such a distance does not exist; in practice, however, we regard waves which have traveled 6 meters or 20 feet as being neutral, and therefore call 6 meters or 20 feet an infinite distance.

Pupillary Distance. The distance between the centres of the two pupils. Also called the pupillary width.

Distance, Judgment of. See **Physiology of Vision.**

Distichia. Rubbing of a double row of eyelashes (on one lid) against the cornea.

Distortion. A phase of aberration in which the linear dimensions of the image do not bear the same proportion to each other as those of the object. It is the opposite condition of being orthoscopic.

Divergence. This term is applied to two straight lines or paths which get continually further and further from each other. Such lines, or paths, if traced backward, would meet somewhere at a common point, and this point could be made the centre of a circle or sphere of which they would be radii. Divergent light waves are those which are traveling away from a point of origin.

Physiologically, divergence signifies the swinging of the visual axes outward, so as to diverge from the middle line, by

means of the external rectus muscles. Strictly speaking, divergence denotes only positive divergence beyond the middle line. Turning outward from convergence to parallelism is negative convergence.

Divergent Strabismus. Strabismus in which the visual axes incline away from each other.

Donders. A famous Dutch ophthalmologist, (1818-1889), who contributed very extensively and originally both to ophthalmology and also to optics. See **History of Optics.**

Donder's Glaucoma. Simple atrophic glaucoma.

Donder's Laws. (1) The age at which asthenopia begins is approximately equal to the denominator of the fraction expressing the degree of hyperopia. (2) The rotation of the eyeball is determined by the distance of the point of fixation from the median plane and the line of the horizon.

Donder's Rings. The circles of yellow seen around lights in glaucoma.

Donder's Test. A test for color blindness made with lanterns with colored slides.

Double Cones. Cones of the retina which occasionally occur in pairs.

Double Image Prism. Two right-angled prisms cemented together so as to form a prism of rectangular section, to split a ray of light into two divergent rays.

Double Prism. A device invented by Maddox, consisting of a prism of 175 degrees so worn that the apex bisects the pupil and produces monocular diplopia, used for testing muscular balance.

Double Refraction. The splitting of a ray of light by refraction through certain crystals. See **Diffraction** and **Polarization.**

Double Vision. Seeing two images of the same object. See **Diplopia.**

Doublet. Two lenses in series, i. e. one behind the other with their principal axes coinciding.

Driver's Test. A test for malingering, to establish the existence of binocular vision. By means of a bar placed at a certain distance between the patient and the test type, if the patient is able to read binocularly, the test demonstrates at once the presence of vision in the pretended blind eye and the visual acuity which that eye possesses.

Drops. A common name for a collyrium.

Duane's Test. A test for muscular imbalance. See Heterophoria.

Duct. A tube or passage for the conveyance of fluid, as the tear duct.

Duction. The power of the various pairs of extrinsic ocular muscles to perform their functions. Duction tests are for determining this power. (See **Adduction** and **Abduction.**)

Dura Mater. The external, fibrous membrane which covers and encloses the entire spinal cord and brain. This covering is extended along the optic nerve, and is continuous with the capsule of Tenon which surrounds the eye.

Dural Sheath. The continuation of the dura mater which surrounds and serves as a sheath for the optic nerve.

Dynamic Refraction. The refraction of the eye with the ciliary muscle in action, i. e. with some accommodation in effect. The theory of this method is that when the accommodative effort is in play the ciliary muscle will more readily accept the help of a lens and surrender its spasmodic contraction, thus enabling us to correct latent hyperopia more fully. The working principle is to ascertain both the subjective and the dynamic findings, and the difference between the two represents the tonic contraction of the ciliary. Dynamic refraction is carried out by means of the retinoscope, and further details of the procedure will be found under **Retinoscopy.**

Dynamic Skiametry. See **Retinoscopy.**

Dynanometer. An instrument for estimating the magnifying power of a lens.

Dyslexia. Difficulty in reading, due to impairment of the brain. See **Alexia.**

Dysopsia. Dysopia. Impaired vision.

Eccentric. Off-centre. Geometrically it is applied to those forms which are derived from the circle, or sphere, but which are no longer circular or spherical,—the parabola, for example. In mechanics, it denotes a form of power-transmission in which the movement is changed from a circular to a parabolic or a side-to-side movement.

Ecchymosis. Extravasation of blood into a tissue, due to rupturing of tiny capillaries. It gives the appearance of a dirty bluish-yellow. What is commonly called a "black eye" is an example of ecchymosis. (N. B. It is pronounced En-ki-mosis).

Echelon Grating. A series of gratings, in echelon formation, for the diffraction of light, devised by Michelson, of Chicago.

Echophotony. Color sensation produced by aerial waves.

Ectasia. Distention of any organ or part.

Ectiris. External part of the iris.

Ectochoroidea. Outer part of the choroid.

Ectocornea. Outer layer of the cornea.

Ectopia Pupillae. A displacement of the pupil.

Ectoretina. External layer of the retina.

Ectropion. Outward eversion of the eyelid. Usually affects the lower lid. It interferes with closing the eye, and breeds infection of the conjunctiva. Operation is the only cure.

Edema. Swelling of the tissues due to accumulation of fluid, usually serum in the interspaces. Edema of the eyelids is usually a symptom of kidney or heart disease, or else is due to a blow or injury which ruptures the small vessels (black eye).

Effective Rays. Those rays of light, out of a pencil, which pass through a refracting medium and fall upon the screen.

Efferent. Literally, the word means carrying outward. In physiology it is applied to those nerve tracts which carry impulses from the centres (brain or cord) to the peripheries of the body. They are also called centrifugal tracts. All the motor and secretor nerves belong in this class.

Egilops. Another name for a lachrymal fistula.

Eidoptometry. Perception of form.

Edridge-Green Theory. A theory of color vision. See **Color.**

Elephantiasis Oculi. Extreme exophthalmia.

Embolism. The blocking of a blood vessel by a clot or plug of some sort floating in the circulation. In the case of an important artery, the function of the part supplied by the plugged vessel abruptly ceases.

In ophthalmology the most serious embolism is that of the central retinal artery, which causes sudden and complete blindness. The affected retinal field becomes white, and, if the embolism is not relieved, optic atrophy ensues.

Embolus. The clot of blood which causes embolism.

Emergent Ray. A ray of light that emerges from a refracting medium, having been acted upon by it.

Emission Theory. The corpuscular, or Newtonian, theory of light.

Emmetropia. A normal state of refraction of the eye, in which, with the eye at rest, (i.e. no accommodation in force), the principal focal point of the refracting system of the eye lies exactly in the plane of the retina, so that neutral waves of light are focussed on the retina. While emmetropia is the normal condition, it is by no means a common one, completely emmetropic eyes being in a great minority.

Emphysema. Air in the tissues. Emphysema of the eyelids is practically always due to wounds of the orbit.

Encanthis. A small tumor in the inner canthus.

Endothelium. A membrane, composed of flat cells, lining the interior of serous and other cavities. It is to the interior what epithelium is to the exterior. The fifth stratum of the cornea is endothelium.

Enophthalmos. Recession of the eye into its orbit.

Enstrophe. A turning inward.

Entochoroidea. Inner layer of the choroid.

Entocornea. Inner layer of the cornea.

Entoptic. Within the eye. In optics the word usually refers to subjective abnormalities of vision which are due to physical bodies inside the eyeball. What are known as "floating specks" are entoptic phenomena.

Entoptoscopy. Examination of the interior of the eye.
Entoretina. Inner layer of the retina.

Entropion. Turning inward of the eyelids. This is a serious condition because the lashes scratch, and even grow into, the cornea, making it opaque and destroying the vision. Operation is the only cure.

Enucleation. Removal of the entire eyeball.

Ephidrosis. Excessive sweating of the eyelids.

Epicanthus. A fold of skin extending from the root of the nose to the inner angle of the eyebrow, overlapping the inner canthus. It is normal in Mongolians.

Epiphora. An overflow of tears. This occurs temporarily under any strong stimulus to the conjunctiva, such as a cold wind, or a physical irritation. Pathologically it is generally due to stoppage of the tear duct.

Episcleral. Situated over the sclera.

Episcleritis. Inflammation of the outer coat of the sclera. It usually appears in the form of a bulging spot of inflamed hardening upon the sclera.

Epithelioma. A form of cancer (carcinoma) which has its rise in the cells of epithelium. It frequently attacks the eyelids, beginning usually at the junction of the lid and conjunctiva.

Epithelium. The non-vascular layer of cells which covers the exterior of skin and mucous membranes.

Equator. A line drawn round a globular body equi-distant from the poles at every point.

Equator of the Crystalline Lens. The peripheral margin of the lens which is inserted into the zonula.

Equator of the Eye. The poles of the eyeball are considered to be the points, anterior and posterior, where the principal axis cuts the circumference. The equator of the eye, therefore, is the meridian mid-way between these two points and at right angles to the axis.

Equilibration. An operation on the extrinsic muscles of the eyes, for the purpose of equalizing their action and securing orthophoria.

Equivalent Lens. A single lens which, placed at a certain fixed point or distance, makes upon a screen the same sized image as a series of two or more lenses at different distances.

Erect Image. A virtual image, such as one gets of the fundus in the direct method of ophthalmoscopy.

Erecting Prism. A prism interposed in a refracting or reflecting system for the purpose of rendering an inverted image erect.

Errors of Refraction. Conditions of the eye which prevent the single focussing of neutral waves upon its retina when the eye is at rest. There are, in reality, but three forms of such error: (1) Hyperopia, in which the principal focal point lies behind the retinal plane; (2) Myopia, where it lies in front, and (3) Astigmatism, where the eye has unequal refracting power in its various (usually two) meridians, so that there are more than

one principal focus. Other errors are combinations of these three.

Erythropsia. A condition in which everything is seen red.

Eserine. An alkaloid of the calabar bean, which, when put into the eye, causes spastic contraction of the ciliary muscle and the concentric muscles of the iris, thus producing contraction of the pupil (myosis). It is employed in 1 per cent solutions of the sulphate. Its chief use is in glaucoma, to lessen intra-ocular tension. It is sometimes employed to counteract the effects of atropine, but is not very effectual. It is also called physostygmine.

Esophoria. Tendency of the eye to turn inward. See **Heterophoria.**

Esotropia. Inward squint. See **Strabismus.**

Eucaine. A synthetic anesthetic resembling cocaine, used in 2% solution in the eye.

Eversion. Turning outward of the eyelid.

Excavation. Another term for cupping of the disc. See **Cupped Disc.**

Exocataphoria. A combination of an outward and a downward imbalance of the eye-muscles. See **Heterophoria.**

Exophoria. Tendency of the eye to turn outward. See **Heterophoria.**

Exophthalmic Goitre. A form of goitre in which the eyeballs are pushed prominently forward from their sockets. Accompanying this symptom is usually another one, viz., that the upper lids do not follow the downward movement of the eye (Graefe's sign). Except for these symptoms, the disease is not properly an eye condition, but a systemic one, due to degeneration of the thyroid gland.

Exophthalmos. Abnormal protrusion of the eyeball outward and forward. It most frequently accompanies certain forms of goitre. (Exophthalmic Goitre.) There is often apparent

exophthalmos in high myopia and conical cornea; but these appearances are due to the size of the ball and the bulging of the cornea, not to pushing forward of the ball.

Exorbitism. Protrusion of the eyeball.

Exotropia. Outward squint. See **Strabismus.**

Extorsion. Rotation outward of the eyeball.

Extrinsic. Belonging to the exterior. The extrinsic muscles of the eye are those which are concerned with the movement of the eyeball. See **Muscles.**

Eye. The organ of vision, as a whole. Aside from its optical aspects, it is made up of three tunics, or coats: (1) the nervous tunic, consisting of the optic nerve and its out-spreading into the retina, (2) the vasculo-muscular coat, comprising the chorioid, ciliary body and iris, and (3) the supporting coat, or sclera.

The entire globe of the eye is almost, but not quite, spherical in shape, the antero-posterior diameter being slightly the greatest, because of the projection of the cornea. The diameters of the adult eye are about as follows, in millimeters:

Antero-posterior	24.3
Transverse	23.6
Vertical	23.3
Depth of anterior chamber	11.9
Thickness of lens at rest	3.7
Thickness of lens at maximum	4.3

Considered as an optical instrument the eye is a series of semi-submerged lenses, whose radii of curvature and indices of refraction respectively are as follows, with air as the index base:

Anterior surface of cornea	7.5 mm.	
Substance of cornea		1.333
Aqueous humor		1.336
Anterior surface of lens	10 mm.	
Substance of lens		1.43
Posterior surface of lens	6 mm.	
Vitreous humor		1.339

The posterior surface of the cornea is omitted, as its action is negligible; the cornea and aqueous humor, having so nearly the same refractive indices, may be regarded as one continuous medium.

With these data, the values of the respective surfaces work out approximately as follows:

Anterior cornea	.33 of	+133	= 44 D.
Anterior lens	.10 of	+100 D.	= 10 D.
Posterior lens	.10 of	+160 D.	= 16 D.

making a total of 70 D. Deducting from this figure 12 D., attributable to the separation of the refracting surfaces and the slight minus action of the posterior cornea, gives a net dioptric power to the eye of approximately 58 D. The location of this value, or the point at which a single thin lens might represent the entire dioptric system of the eye is at the posterior nodal point, .4764 mm. anterior to the posterior surface of the crystalline lens.

The optic axis of the eye pierces the center of the cornea, normal to its curvature, and passes through the geometric center of the eye-ball. Situated along this axis are three sets of cardinal points, one set for each refracting surface. For the sake of convenience, however, we merge them into one set, using as a basis a single refracting surface having the same net dioptric power and principal focal point as the compound system—known as the reduced eye. These points will be found to be as follows:

The principal point, where the imaginary surface referred to cuts the axis, 2.3448 mm. behind the anterior surface of the cornea.

The principal anterior focus, 12.8326 mm. in front of the same surface.

The posterior principal focus, 22.647 mm. behind the same surface.

The nodal point, .4764 mm. in front of the posterior surface of the crystalline lens.

The radius of this imaginary surface would be 5.1248 mm.

The center of rotation, around which the eyeball rotates, is

a matter of some dispute, but is probably 13.5 mm. behind the anterior surface of the cornea, also on the principal axis.

The eye has various other axes and angles, all of which are described under the headings **Axis** and **Angle.**

The iris, with its power of contraction and expansion, serves as a cut-off, to protect the retina from excessive light, and to insure against peripheral spherical aberration. The retina is the sensitive film of the camera; and the sclera is the dark box, maintaining its hollow, globular shape. (For further details see **Anatomy of the Eye.**)

Eyebrows. Two projecting arches of skin over the upper borders of the orbits, covered with short bushy hair, which serve to protect the eyes from above.

Eyelashes. Soft, silky hairs that grow upon the margins of the upper and lower eyelids. They protect the eyes from the outside. The follicles which form the roots of these lashes not infrequently become infected, and give rise to what are known as styes.

Eyelids. Folds of external skin which push their way over the eyeball to cover and protect it, above and below. The boundaries of the upper lids are formed by the eyebrows, but the lower lids pass imperceptibly into the skin of the cheek. The space made between the two lids, when opened, is called the palpebral fissure.

The skin covering the eyelids is about the thinnest in the body. Beneath the skin are the muscles by which the lids are moved (the orbicularis palpebrarum and the levator palpebrae superioris), and the cartilaginous substance which gives them shape (the tarsus). On the inner surface the lids are lined with reflected conjunctiva, under which are the Meibomian glands and sebaceous glands, both of which secrete lubricant for the lids. Along the margins of the lids are hair follicles from which the lashes grow.

For minute anatomical details of the lids a work on anatomy must be consulted. Optically, they are merely shutters, for preventing light from entering the eye.

Eyepiece. The lens, or combination of lenses, at the end of an optical instrument, such as a telescope, microscope, etc., where the observer's eye is applied.

Eye, Schematic. An artificially constructed model of the eye, so constructed as to serve as a model upon which the student can practice retinoscopy and ophthalmoscopy.

Facial Paralysis. Paralysis of the seventh cranial nerve, which supplies all the muscles of the face and the orbicularis palpebrarum on the same side as the nerve. Not only is it impossible to move the paralyzed side of the face, but the paralyzed muscles become entirely flaccid, so that all the creases and wrinkles of the face are smoothed out. So far as the eye is concerned, the important thing is that the lid cannot be closed; the eye remains permanently open, and soon becomes inflamed and the cornea dulled from constant exposure.

Facultative. This term is applied to a physiologic disability under which the patient is still able to function normally. Thus, facultative hyperopia is a condition of hyperopia in which the patient can still exercise clear distant vision.

False Image. The image made upon, and seen by, the deviating eye in genuine strabismus. The image is, of course, really no more false than that of the sound eye, but is projected to a false position.

False Myopia. Where a person has a spasm of the ciliary muscle, the crystalline lens being thus kept continually in an excessively convex curvature, the condition simulates myopia, and is sometimes mistaken for it, and careless practitioners not infrequently give such patients minus glasses. This is known as false myopia.

False Projection. When light from an object has been deviated, as by a prism, before entering the eye, the brain projects the rays back in a straight line, and the object thus appears to be in a position in space different from that which it actually occupies. This is known as false projection. (See **Projection.**)

Far Point. See **Accommodation** and **Convergence.**

Far-Sight. A popular name for hyperopia.

Fascia. A band of connective tissues covering and connecting muscles.

Fatigue-Field. The limits of the field of vision found in neurasthenics. See **Perimetry.**

Fereol-Graux Palsy. Paralysis of the external rectus of one eye and the internal rectus of the other. Of cerebral origin.

Field, Retinal. The area of the retina over which the stimulation of light produces the sensation of vision. This extends practically over the entire area of the retina, the acuity of vision being keenest at the fovea centralis, and diminishing concentrically in direct ratio to the distance from that spot. Variations in shape and scope of the visual area are not, as a rule, due to retinal conditions (except in disease), but to conditions which govern the entrance of light into the eye, and pertain to the visual field. The whole subject will be treated under the heading of the visual field. See **Field, Visual.**

Each retinal field is divided into two lateral halves, known as the nasal and temporal halves respectively, by reason of the decussation of the optic nerve fibres from these two halves at the optic chiasm.

Field, Visual. The area in space which the vision is able to compass. The monocular field is the area which one eye alone can compass; the binocular field the area which both eyes together can take in.

If waves of light did not cross at the nodal point, the visual field would be limited to the size of the pupillary aperture; but the crossing of the rays permits of a visual area as large as the angular separation of the two lines forming the visual angle. The form of the visual field depends upon the way in which the light enters the eye, and this is modified by certain interruptions or cut-offs. Notably, the entrance of light from

the nasal side is considerably cut off by the nose, so that the visual field on that side is markedly limited over that on the temporal side. The normal forms of the visual fields for the two eyes is as shown in the accompanying cut.

Physiologically, the visual field may be considered as central and peripheral. The central field is represented by those light waves which fall upon the macula. These images alone we see with clearness and attention, and as they fall on symmetrical spots in the two retinae, these images are exactly superimposed on each other and appear as one. From the peripheral field the light falls on the peripheral parts of the retina, making images which are less keenly perceptible and more or less blurred, being less accurately focussed and falling upon less sensitive rods and cones. Moreover, these images are not made on symmetrical points in the two retinae; hence images from the peripheral field are double, and overlap each other. However, they are good enough images to protect us as we move around, and to call our attention to objects which we wish to "fix" and to view attentively. Again, owing to the interposition of the nose, there is a certain portion of the visual field on each side which is represented only on the retinal field of each eye, respectively, on the temporal side. The rest of the visual field overlaps in both retinae.

The visual field is explored and measured by means of an instrument called the perimeter (q. v.). Diseases of the retina produce characteristic changes in the field, which serve as means of diagnosis.

The differences in the peripheral visual field of the two eyes, i. e., the different views which each eye has of the objects which are seen, play an important part in what is known as the stereoptic sense, i. e., the perception of solidity, and are made use of in the construction of stereopticon instruments. (See **Binocular Vision.**)

Fifth Nerve Paralysis. The fifth cranial nerve mediates sensation for practically the entire head and face, including the eyeball. When, therefore, the ophthalmic branch is involved in

paralysis of the nerve, the winking reflex of the cornea is lost, the eye becomes dry, dust accumulates on the conjunctiva and the cornea, with resulting inflammation and destruction of corneal transparency.

Finder. A device on any optical instrument which enables us to find the focus necessary to the functioning of the instrument.

Fissure, Palpebral. Opening between the margins of the eyelids.

Fixation. In physiologic optics this term is applied to the holding of the accommodation and convergence of one eye (monocular fixation) or both eyes (binocular fixation) for a given point of distance.

Fixation Line. The line joining the point of fixation with the center of motility of the eye or eyes.

Fixation Test. Test of the near point of fixation.

Flap Extraction. A method of extracting a cataract by making a flap in the cornea.

Floating Specks. Small floating opacities in the vitreous, seen by the patient. See **Muscae Volitantes.**

Fluorescence. The property of rendering visible, as light, the actinic or ultra-violet rays, or of becoming self-luminous when exposed to such influences.

Fluorscope. An instrument for observing the effects of non-visible rays by means of their action upon a fluorescent screen. Most commonly used in connection with Roentgen rays.

Focal. Pertaining to a focus.

Focal Planes. Plane surfaces passing through focal points at right angles to the principal axis of the focal system.

Focal Point. The point at which a light wave is brought to a focus.

Focal Distance. The distance from a refracting or reflecting surface to the focal point.

Focal Length. Focal distance as a property of the lens or mirror. The focal length is found by dividing the dioptres in 1.

Focus. The point at which a wave of light reverses itself from a minus into a plus wave. Every wave of light originates in a point, and expands in the form of a sphere. If nothing interferes with it, it will continue to expand infinitely. If, however, a convex lens or a concave mirror of greater curvature than the wave be interposed in its path, the lens or mirror will reverse the curvature of the wave and cause it to diminish to a point similar to the point from which it originated. Passing this point, it will be again reversed into an expanding (plus) wave, and again continue to expand until another lens or mirror interrupts it. The point at which this reversal takes place, under the influence of the lens or mirror, is called the focal point, because all of the light contained in the wave is there concentrated in that point.

Geometrically, the focus is represented by the meeting and crossing point of two or more straight lines forming the radii of the wave curve. This leads to an erroneous conception in the mind of some students that the focal point of a lens or a mirror is the point where the refracted waves meet and cross each other. That point is the nodal point, which in a spherical lens is in front of the focus, so that the waves have all crossed before they are brought to a focus.

For details of the focus and its geometrical relations, see **Lens.**

Fogging. A technical name given to a method of testing the refraction of the eye by first rendering it highly myopic by means of a strong convex lens, and then gradually reducing the plus power by means of minus lenses, thus moving the light focus back until it reaches the retina and gives the patient clear vision. The latter part of the process is known as bringing the patient out of the fog.

The principle of the fogging system is to force a relaxation of the ciliary muscle, so that the testing may be done with the accommodation at complete rest. It takes the place of the old practice of the ophthalmologist of paralyzing the ciliary with a drug. (See **Hyperopia.**)

Follicle. Small secretory sac. The hair follicles in the eyelids, containing the roots of the lashes, and the lymph follicles of the conjunctiva, are ophthalmological examples.

Follicular Conjunctivitis. A form of conjunctivitis in which there are small elevated spots, or follicles, in the membrane. It usually attacks the lower lid. Errors of refraction aggravate the condition.

Fontana's Spaces. The triangular spaces between the sclera and the root of the iris. They are supposed to play a part in the causation of glaucoma (q. v.).

Foramen. An opening in bone for the passage of vessels, nerves, etc. The one foramen of interest in ophthalmology is the Optic Foramen, through which the optic nerve and its accompanying vessels enter the orbit. (See **Anatomy.**)

Foreign Bodies in the Eye. This term, as commonly employed, refers to small particles of matter, such as stone, metal, cinder, emery, etc., which become lodged in the conjunctival sac or on the exterior of the eyeball. They immediately set up a very violent irritation, causing profuse flow of tears, redness and swelling of the conjunctiva, and more or less acute pain.

If the foreign body is lodged in the lower conjunctival fornix, it can be readily removed by drawing down the lower lid and catching the offending particle on a little piece of cotton twisted on the end of a toothpick or probe. If it be under the upper lid, the lid must be turned back,—best accomplished by laying a smooth probe or rod along the upper part of the eyelid, where it lies on the eyeball, telling the patient to look down at his feet, taking hold of the lashes, and turning the lid over the probe,—and the same method applied as in the case of the lower fornix.

If the particle be of a hard substance and is bedded in the cornea its removal is rather more difficult. It must be dug out

with a small pick, for which operation a little cocaine is usually needed, as the cornea is exquisitely sensitive. Great care must be taken not to dig too deeply, so as to penetrate the corneal epithelium and wound the external limiting (Bowman's) membrane.

Usually, after a foreign body has been successfully removed all the inflammatory trouble quickly subsides and the eye returns to normal within a few hours. There is always the possibility, however, of infection, especially where the cornea has been wounded. It is better to follow removal from the cornea by a good flushing of the eye with saturated solution of boric acid.

Foreign bodies which penetrate the cornea and enter the interior of the eye are a much more serious affair, and belong wholly to the sphere of the expert eye surgeon.

Fornix Conjunctivae. The angle of the conjunctiva where it is reflected from the bulbar to the palpebral portion.

Fossa Patellaris. The concave depression in the vitreous body in which the posterior surface of the crystalline lens lies. Also called the Hyaloid Fossa.

Four Dot Test. A test devised by Worth for binocular vision. It consists of four circular holes in a diaphragm, arranged in diamond form, having a red glass in the top hole, green in the two lateral holes, and white in the bottom one. The patient wears a red glass before the right eye and green one before the left. If he sees two dots, black and white, he is using the right eye only. If three dots, white and two green, the left eye only. If four dots, he uses both eyes. If he sees five dots, red, two green and two white, he has diplopia.

Fovea Centralis. The small depression in the center of the yellow spot which forms the keenest center of retinal acuity. See **Retina.**

Frame Fitting. There is nothing of greater importance in the fitting of glasses than fitting the frames or mountings, for if the lenses do not set properly before the eyes satisfactory results cannot be expected.

THE SPECTACLE BRIDGE.

There are two ways of expressing the dimensions of a bridge: By giving each dimension in figures or by using the size letter and number. The dimensions considered are height, inclination of crest, angle and width of base. The following letters are used to designate the width of bridges, beginning with the smallest: L, M, N, O, P. The heights are expressed in combination with the letters by numbers, as ½, 1, 1½, 2, etc. The shanks are called regular, long and extra long. With the regular shanks the lenses are held a trifle closer to the eyes than the crest of the bridge; with long shanks the lenses and crest of bridge are on the same plane; with extra long shanks the lenses are further from the eyes than the crest of bridge is. Thus to set the lenses away from the eyes to escape the lashes, etc., we use long and extra long shanks. When no length shank is stated "regular" is understood. This is the way the different sizes of bridges are expressed: M, M½, N2 extra long shanks.

When the sizes are not specified as above it is necessary to give all the dimensions in figures. The height of bridge is the distance above or below a line running through the center of the lenses to the lower edge of the center of bridge; the inclination of the crest is the distance from the inside plane of the lenses to the upper edge of the middle of the bridge and is specified "in" or "out," meaning in back or in front of the lenses, respectively. The angle of the bridge is considered with respect to the plane of the lenses, the latter being 90 dgrees. The angle is measured at the center or crest of the bridge.

DIMENSIONS OF SADDLE BRIDGES.

(Upper figure Inches, lower figure Millimeters).

Bridge.	Height.	Crest.	Base.
L	0 0	0 0	5/8 15
L½	1/16 1½	0 0	5/8 15
L1	1/8 3	0 0	5/8 15
M	0 0	1/16 1½	5/8 15
M½	1/16 1½	1/16 1½	5/8 15
M1	1/8 3	1/16 1½	5/8 15
M1½	1/16 4½	1/16 1½	5/8 15
M2	1/4 6	1/16 1½	11/16 17
N	0 0	1/16 1½	3/4 18
N½	1/16 1½	1/16 1½	3/4 18
N1	1/8 3	1/16 1½	3/4 18
N1½	1/16 4½	1/16 1½	3/4 18
N2	1/4 6	1/16 1½	3/4 18
N2½	3/16 7½	1/8 3	11/16 20
N3	3/8 9	1/16 1½	11/16 20
O	0 0	0 0	7/8 21
O1	1/8 3	1/16 1½	7/8 21
O2	1/4 6	1/16 1½	7/8 21
O3	3/8 9	1/16 1½	13/16 23
P1	1/8 3	1/16 1½	1 25
P2	1/4 6	1/16 1½	1 25
P3	3/8 9	1/8 3	1 25

TEMPLES.

The length of temples is measured from tip to tip, that is, from the screw hole to the extreme other end. The average length is six inches, but they are also made in lengths of 5½, 6½ and 7 inches.

SIZES OF LENSES.

Lenses are always measured in millimeters, to indicate length and width as 41 mm. x 32 mm. meaning 41 mm. long and 32 mm. wide. There are certain standard sizes such as 000 eye, 00 eye, 0 eye, 38 mm. oval, 40 mm. oval, 38 mm. short oval, etc. There are certain standard shapes such as oval, short oval, drop, and round.

The following table shows the dimensions of the standard sizes:

STANDARD SIZES OF EDGED LENSES

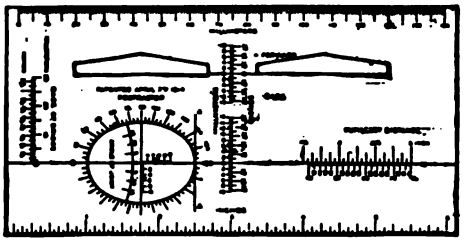
	44 mm		42 mm		40 mm		38 mm	
	Size	No.	Size	No.	Size	No	Size	No.
Round	44	440	42	420	40	400	38	380
Oval	48 x 39	449	46 x 37	429	44 x 35	409	42 x 33	389
Full Oval	47.2 x 40.2	447	45.2 x 38.2	427	43.2 x 36.2	407	41.2 x 34.2	387
Drop Eye	45.7 x 42.2	443	43.2 x 40.2	423	41.2 x 38.2	403	39.2 x 36.2	383

	000		00		
	Size	No	Size		No.
			Bevel	Rimless	
Round	—	—	35.6	35.6	3540
Oval	41 x 32	3689	39.7 x 30.7	40. x 31	3549
Full Oval	39.8 x 32.8	3687	38.7 x 31.7	40. x 33	3547
Drop Eye	37.8 x 34.8	3683	36.7 x 33.7	36.7 x 33.7	3543

	0			1		
	Size		No.	Size		No.
	Bevel	Rimless		Bevel	Rimless	
Round	—	—	—	—	—	—
Oval	37.8 x 28.8	38.5 x 29.5	3359	36.5 x 27.5	37 x 28.	3289
Full Oval	36.8 x 29.8	38.5 x 31.5	3357	35.5 x 28.5	37 x 30	3287
Drop Eye	—	—	—	—	—	—

The cut on this page illustrates a measuring card used for measuring spectacle frames. Your wholesale house will supply you with one of these cards.

To measure P. D. and height of bridge, place end pieces on line A-A with inner edge of left eye at line B. The figure at right end of right lens indicates the pupillary distance and



Protractor.

that at under edge of bridge crest indicates the height of bridge.

To measure bridge crest, forward or back, place lenses in slots, top down, with inner surface of lenses on lower edge of slots. That edge of bridge resting on card will indicate position of crest.

It will be noticed that in measuring the "pupillary width" of spectacles and eyeglasses, a similar plan is followed as when measuring over the eyes; that is, the distance is taken from the nasal edge of one lens or rim to the temporal edge of the other lens or rim. This is most conveniently accomplished by using the measuring card designed for this purpose shown here.

THE PUPILLARY DISTANCE.

The first thing for consideration is the distance between the pupils. What we desire to know is the exact distance from the center of one pupil to the center of the other, but as it is impracticable to measure from these points we measure from the nasal side of the right iris to the temporal side of the left iris which gives the desired result. To obtain the Pupillary distance, or P. D., as it is generally termed, for glasses for general use, for both near and far, have the patient fix his eyes on an object a couple of feet in back of you and with a millimeter rule in your right hand proceed to measure. First close your right eye and sight the zero of your rule over the nasal edge of the patient's right iris, then close your left eye and open your right and with it read the figure on the rule directly opposite the temporal side of the patient's left iris. To get

the correct distance between the centers of the lenses for reading distance close one eye and direct your patient to look into your open eye and make all your readings with this one eye. In the latter case your eye should be at 12 or 14 inches in front of your patient's eyes.

DETAILS FOR SPECTACLES.

Before starting to ascertain the correct sizes for spectacles you should be provided with a rule graduated in millimeters and inches, one that is about six or six and a half inches long. It is preferable to make all measurements in millimeters as this method is much simpler and there is less likelihood of making errors. Temples, however, are regularly expressed in inches, such as 6 x 6½, and 7 inches, therefor the need of the inch scale. You also need a complete fitting set of spectacles.

After measuring the P. D. as already explained select from the fitting set the spectacle frame having a bridge that comes nearest to fitting the patient's nose and note the letter and figure that represents this size. If there is no regular stock size of bridge that will fit the patient it will then be necessary to measure so as to give the exact specifications for height, width of base, position of crest and angle of crest, but most cases can be satisfactorily fitted from the fitting set.

LENGTH OF TEMPLES.

There are two ways of expressing the length of temples desired, i. e., the distance to back of the ear or the entire length of the temple from tip to tip. The first measurement is made with the fitting spectacles on the patient's face, the two extreme points being the plane of the lenses and the middle of the back of the ear. The other method is to notice how the length of the temples on the fitting frame suits, measuring the full length of these temples and then adding to or subtracting from this length as may be necessary.

The instructions given here apply to both rimless and frames. Some use four or five spectacles of different sizes to measure over, but the use of a complete set of 12 sizes is strongly advised.

EYEGLASSES.

The finger-piece type has come into use within the last ten years and on account of neatness of appearance, the property of retaining its original shape and adjustment, and simplicity in fitting, it has become very popular and widely used. However, there are cases where the regular style is more

Finger-Piece.

Regular.

desirable than the finger-piece and vice versa. For instance, a finger-piece mounting has a tendency to cause the nose to appear shorter and the face narrower, while the regular mounting gives rise to reverse impressions. This being the case if you put a finger-piece mounting on a short nose you make it seem shorter; a regular mounting would lengthen it. If you fit a finger-piece mounting where the pupillary distance is comparatively narrow, the eyes will seem still closer together, whereas a regular mounting will seem to put more space between the eyes.

"REGULAR" STYLE.

To ascertain the correct size of lens, length of stud, style of guard, etc., it will be quite necessary to have an eyeglass mounting to measure over.

First measure the patient's P. D. Then adjust your sample mounting as well as you can and place it in the correct position on the patient's nose. Now measure the P. D. of the glasses while on the face (measure from inside edge of one lens to outside of the other); this places you in position to know how large to make the lenses and how long the studs. Suppose, for illustration, that the sample mounting is equipped with regular B studs and 0 eye lenses, that your patient's P. D. is 60, and that the P. D. of the glasses, when on, is 58 millimeters. You see at a glance that these glasses would be too narrow and their P. D. must be increased 2 millimeters.

There are two ways in which this can be accomplished; by using longer studs or larger lenses. The next size studs to

those on the sample mounting are known as C studs, there being a difference of one millimeter in the length of a B and a C. By using C studs in the case we are considering we will increase the P. D. of the glasses 2 mm. (1 mm. on each stud), and thus obtain the desired width of 60 mm. By increasing the size of lenses 2 mm. and leaving the studs as they are in the sample (B size) we can obtain the same result. The lenses in our sample are 0 eye size and their length therefore is 39 mm.; adding 2 mm. to this gives 41, which is the length of 000 eye lenses, hence by using 000 lenses and B studs we obtain the desired P. D. With these two methods we can make several combinations and get exactly the dimensions we want. For instance, we have studs ranging from A to F (about 1 mm. difference for each size) and lenses ranging from 1 eye to jumbo, or in figures, from 37 to 46 mm. long, which we can combine in a great many different ways.

Notice when the mounting is in the proper position on the nose whether the lenses are too close to or too far away from the eyes. If they are too close use inset studs to put them farther out, if too far away use outset studs to bring them closer. Both of these styles are made in two sizes, 1-16 and 1-8 inch, and you can easily tell which size is required.

If the brows are prominent and press against the spring use a Grecian or a tilting spring. Oblong springs are usually used for men and hoop springs for women, but this is a matter of personal choice.

The guards selected should have a flat surface where they come into contact with the flesh—this is the first requisite of an efficient guard. In adjusting the guards it must be borne in mind that contact and adhesion count greater for desirable results than pressure, and for this reason the guard must be curved and bent to conform with the corresponding part of the nose.

You should have about six eyeglass mountings, complete with lenses, and having different styles of guards and springs. With this equipment you can select the style of guard that will be best for each particular case.

Some styles and angles of guards will set the lenses lower than others, but usually it is necessary to drill the holes in

the lenses 1-16 or 1-8 inch above center to lower them, especially where the glasses are to be bifocal or reading lenses, in regular eyeglass mountings.

FINGER-PIECE EYEGLASSES.

You must be provided with a complete fitting set of some good make of mountings. Do not make the common mistake of getting a few mountings of several kinds, but get a full set of some one particular style; if they are good mountings, with the proper adjustment, they can be made to fit any nose that could wear the eyeglasses, and by getting a full set you have the entire range of numbers and sizes to select from.

With the fitting set at hand, select the mounting that comes nearest to fitting, take your pliers and adjust the mounting so that it will assume just about the same position that the mounting you order will when adjusted. Some manufacturers do not advise adjusting the mountings in the fitting set, but experience proves that it is better to do this, for you are then in position to know definitely whether the mounting can be made to fit or not, and to accurately ascertain the size of lenses and the kind of posts required.

Having decided what mounting fits the best, note the number it bears that represnts its size. Measure the P. D. of the patient and then measure the P. D. of the glasses. If these two measurements are alike prescribe the same size lenses as those in the fitting mounting, which is usually O eye size. If the fitting glasses are too narrow in P. D. increase the size of the lenses until the proper P. D. is obtained, provided of course that it is not more than a few millimeters and does not make the lenses too large. The 00 eye lenses are one millimeter longer than 0 eye size and will increase the P. D. just one millimeter; 000 eye lenses are two millimeters longer than 0 eye and will increase the P. D. the same amount. You do not have to be controlled, however, by the standard sizes; 000 eye lenses have a length of 41 mm., you can use 42, 43, or 44 mm. lenses if you desire. There is usually about 9 mm. difference between the length and breadth of regularly shaped lenses, so you can specify 42 x 33 or 43 x 34, etc., instead of

trying to convert these lenses to a standard size. Likewise where it is desired to give a short oval effect you may specify 42 x 34 or 42 x 35, etc., but always remember that when you measure the P. D. of a pair of glasses you measure from the inside edge of one lens to the outside edge of the other lens and in this way the length of only one lens is included in the total P. D. and consequently an increase in the length of both lenses of 2 mm. will increase the P. D. of the glasses only 2 mm. and not 4 mm. as might at first be supposed.

Let us say that, in order to cause the glasses to have the proper P. D. it would be necessary to use larger lenses than are desired. In this case you must use extended posts; these correspond to the C and D studs in regular eyeglass mountings and are made in just two sizes, 1-16 and 1-8 inch. Should you put on 1-16 extended posts you will increase the P. D. ⅛ inch or about 3 mm. and ⅛ inch extended posts would increase the P. D. ¼ inch or about 6 mm. Here it will be seen that both posts must be considered in the P. D. as we include them both in the P. D. measurement.

Now observe whether the lenses are too close or too far from the eyes, if so prescribe inset or outset posts, whichever set and inset posts are made in two sizes, 1-16 and 1-8 inch, and it will be found comparatively easy to judge which size are needed, the same as when fitting regular mountings. Out- is needed.

Summing up, the things we need to know in prescribing finger-piece eyeglass mountings are: The number or size of the mounting, extended, inset or outset posts and the size of the lenses.

In fitting glasses that contain bifocal lenses care must be exercised to get the P. D. exactly right, remembering that the P. D. for reading is usually about 3 mm. less than that for distant vision so that the reading segments must be moved nasalward. The lenses also should set a trifle lower than single-focus lenses so that the reading segment will not interfere with the patient's distant vision and the lenses should also tilt slightly forward so the stronger or reading portion of the lenses will be more closely at right angles with the patient's

line of vision when the eyes are directed downward in the natural position assumed when reading.

Franklin, Benjamin. A famous American statesman, who invented bifocal glasses. See **History of Optics.**

Franklin Glasses. Bifocal glasses, invented by Franklin.

Function. In physiology the term denotes the work or office of each separate organ (special function) or of the body as a whole (general function). In mathematics a quantity is said to be the function of another quantity when a modification of the former involves a corresponding modification of the latter.

Fundus Oculi. All that part of the eye back of the vitreous which is visible through an ophthalmoscope, including the retina, chorioid, pigment, vessels, optic disc, etc. (See **Ophthalmoscopy**).

Fuscin. A rich brown pigment. Such a pigment exists in the retinal epithelium.

Fusion. In physiologic optics this word signifies the faculty of superimposing the two central images of the retinae and projecting them into space as one single image.

Next to the desire for a clear image,—perhaps equal to it,—is the imperative desire of the brain for a single image. No doubt it would be more correct to say that the desire for a single image is part and parcel of the desire for a clear image, since an image can hardly be double and clear at the same time. Just as the desire for clarity will impel the brain to use every available means for focussing, up to the last ditch of its capacity, so will the desire for singleness of vision lead the brain to use the last shred of its converging capacity.

The mechanics of fusion will be found discussed under **Convergence.** It is generally supposed that there is, in the frontal lobe of the brain, a fusion centre which controls this faculty. The whole performance is one of co-ordination, similar to standing and walking. The re-education of the faculty is the prime factor in the cure of squint or imbalance, just as

we have to re-educate the co-ordination of the locomotor ataxia patient. It is important to distinguish between this education of the co-ordination and the sheer exercise of the muscles.

Galeropia. Galeropsia. Abnormal keenness of vision.

Ganglion. An aggregation of nerve cells within the brain or along the course of a nerve. Often a ganglion serves as a point of junction or exchange between the cerebro-spinal and the sympathetic nerve systems. This is the case with the important ganglion of the eye, described below.

Ganglion.—Ciliary. A nerve ganglion situated between the optic nerve and the external rectus muscle of the eye. It has three roots: (1) A long, sensory root, from the nasociliary nerve, (2) a short, motor root from the oculomotor (third nerve), and (3) a sympathetic root. It gives origin to the short ciliary nerves which go to the coats of the eyeball, the ciliary muscle, and the iris. Impulses sent out along the third nerve are here relayed to the short ciliary nerves.

Ganglion.—Gasserian. A ganglion lying in the fossa on the anterior part of the petrosa, near the apex. Its chief interest in ophthalmology is its removal for the relief of trigeminal neuralgia and consequent keratitis.

Generic Compounds. Compound lenses whose curvatures are developed in similar ways, i. e. whose curvatures are of the same kind, the sphere and cylinder both convex or both concave. When the curvatures are opposite the lenses are called contrageneric.

Geometrical Centre. The one point in a sphere or circle which is equidistant from all points in the circumference. The geometric centre of a lens or mirror is the geometric centre of the sphere of which it is a segment.

Geromorphism. A skin disease affecting the upper eyelid and occasionally producing ptosis.

Glabella. The little prominence of the skull immediately between the two eyebrows. From the glabella to the occiput (the

prominence at the back of the head) is the longitudinal measure of the skull.

Gland. An organ which elaborates a secretion. In ophthalmology are the

Lachrymal Glands, which secrete the tears.

Sebaceous Glands, which secrete an oily substance for lubricating the eyelids and eyeball, and

Meibomian Glands, which are really larger sebaceous glands.

Glass. A brittle, transparent substance, composed of silica, potash and lead, used for making lenses. The index of refraction depends upon the relative proportions in which the ingredients are combined. Crown glass, which is commonly employed in ordinary lenses, has an index of about 1.53. Flint glass, in which a larger proportion of lead is used, has an index of from 1.65 to 1.70. The former has a higher fusion point than the latter, which permits the fusing together of segments of the two for the making of bifocal lenses. (See **Bifocal**).

Glaucoma. A serious disease of the eye in which there is greatly increased intraocular tension, the cause of which is not definitely known, but supposed to be an impairment of the functions of the canal of Schlem and the spaces of Fontana (q. v.), so that the anterior chamber is not adequately drained. The disease may be acute or chronic; primary or secondary, i. e. self-originating or following some inflammatory disease. The cardinal symptoms are:

Severe pain
Tension and hardness of the globe
Failing accommodation
Dimness of vision
Colored halos seen around a light
Cupping of the optic disc
Steamy cornea.

The use of atropine in the eyes of persons over forty is apt to produce glaucoma, because it crowds the iris into the area of the spaces of Fontana, and increases ocular tension.

Glaucomatous. Pertaining to glaucoma.

Glioma. A malignant tumor which occasionally invades the retina.

Glio-Sarcoma. A combination of glioma with sarcoma.

Globulin. A protein substance contained in the crystalline lens.

Goggles. Large, hollow glasses for the protection of the eyes in industrial work, automobiling, etc. For industrial purposes they are usually furnished with wire screens.

Goitre. Disease of the thyroid gland. The only form which interests the ophthalmologist is Exophthalmic Goitre, q. v.

Gonorrheal Ophthalmia. A violent inflammatory disease of the eye due to invasion by gonococci. It first attacks the conjunctiva, causing intense redness, swelling, pain, and photophobia, followed in a day or so by thick, profuse, yellow discharge. If not quickly checked, it attacks the cornea, and the interior structures. Indeed, an eye is frequently destroyed by the disease in forty-eight hours. It is usually unilateral, except in little children, who carry infection to the eyes with their fingers indiscriminately. The disease is highly contagious, and calls for prompt isolation and treatment.

Gould's Sign. Bowing of the head to obtain better vision in retinitis pigmentosa.

Graduated Tenotomy. An incomplete cutting of the tendons of the rectus muscles to effect a slight amount of straightening of the eyes.

Graefe's Test. A test for heterophoria by means of a prism, base up or base down, before the eye, to double the image. See **Heterophoria.**

Granular Lids. See **Trachoma.**

Groove. In anatomy, a crease or furrow, in which some structure usually lies.

Lachrymal Groove. The groove which lodges the lachrymal sac.

Optic Groove. A groove on the superior surface of the sphenoid bone in which the optic commissure rests.

Haab's Reflex. Contraction of the pupil when, in a darkened room, the patient's attention is directed to a light placed to one side of him, the eyes, however, not being turned toward it.

Haidinger's Brushes. An appearance produced when polarized light from an evenly illuminated surface falls on the eye. See **Polarization.**

Hair Optometer. An English instrument for measuring the accommodation, consisting of a frame like a miniature harp, the strings being replaced by small hairs. The patient holds this against a white background, and gradually brings it nearer to his eye until he can distinguish the hairs. The distance from the instrument to the eye is then measured by a steel tape, graduated into centimeters and dioptric values.

Haller's Circles. Arterial and venous circles in the eye.

Haller's Tunic. The vascular (second) tunic of the eye.

Halo. A reddish-yellow ring of color surrounding the optic disc, due to widening of the scleral ring.

Halo Symptom. The sensation of colored rings around a light. It is a frequent symptom of glaucoma.

Haplascope. In general, any instrument for measuring the visual axes. Hering's haploscope is an apparatus for presenting a special field of vision to each eye, while the two are united in consciousness. The figures consist of two vertical lines, separated by the interpupillary distance. One line runs vertically upward from a point representing the pupillary centre; the other runs vertically downward from a point representing the other pupillary centre. When each eye fixes its own central point, stereoscopically, the two lines are seen as one continuous line, which, however, is not straight and vertical, but bends at the junction of the two lines at an obtuse angle, which can be measured angularly by means of the apparatus.

Haplopia. Single vision, as distinguished from diplopia.

Hectometer. One hundred meters.

Helcosis. Ulceration.

Helmholz. A famous physiologist and oculist. See **History of optics.** See, also, **Accommodation, Color.**

Hematoma, Ocular. Formation of blood clots in the vascular tissues of the eye.

Hemeralopia. Day blindness.

Hemiablepsia. See **Hemianopia.**

Hemiachromatopsia. Color blindness in half of each retina.

Hemiamblyopia. Amblyopia in half of each retina.

Hemianopia. Also written **Hemianopsia.** Blindness of one half of each retina. When the two corresponding sides are blind, i. e. both right or both left halves, it is called homonymous hemianopsia; when the non-corresponding sides, it is called heteronymous hemianopsia. In the latter case, we designate it as either nasal or temporal hemianopsia. It is usually due to grave brain lesions; but occasionally to hysteria.

Hemierythropsia. Red vision in half of the field.

Hemophthalmia. Extravasation of blood into the eye.

Hering's Theory. See **Color.**

Heterochromia. A mixture of color-pigments, as in the iris or the retina.

Heterometropia. Unequal refractive power in the two eyes.

Heteronymous. Applied to bilateral affections which are unsymmetrical or non-corresponding. See **Diplopia** and **Hemianopsia.**

Heterophoria. In the section on **Convergence** it has been shown that in a normal pair of eyes the following conditions obtain in the matter of the ocular muscles:

(1) There is stable equilibrium between the various pairs of antagonistic muscles when vision is directed to infinity; i. e., the far point of convergence is at infinity.

(2) The amount of convergence exerted for any given distance within infinity is equal, in prism dioptres, to the distance (in meters) divided into half the pupillary width (in centimeters).

(3) The total amount of convergence achievable, with the accommodation in effect, is approximately 30 to 32 prism dioptres; i. e. the near point of convergence is approximately 10 cm.

Any marked departure from these conditions indicates a defect in the working of the muscles, and constitutes heterophoria, or muscle imbalance.

From the standpoint of resultant effect, i. e. the position assumed by the eye in a state of stable equilibrium, heterophoria is classified as follows:

Esophoria. Turning inward.
Exophoria. Turning outward.
Hyperphoria, or Anaphoria. Turning upward.
Hypophoria, or Cataphoria. Turning downward.
Cyclophoria. Turning obliquely.

We may also have combinations of these varieties, hyperesophoria, hyperexophoria, catesophoria, catexophoria, etc.

From the point of view of the underlying cause, we distinguish between (a) imbalance due to anatomical conditions, and (b) imbalance due to errors of refraction.

Strictly speaking, manifest heterophoria is heterotropia. That is to say, where the patient has never attempted, or has ceased the effort, to overcome the imbalance, so that the eyes take up a constant position of stable equilibrium, in or out or up or down, the condition ceases to be one of muscular imbalance and becomes a squint, which will be treated of in a separate section. By manifest heterophoria, however, we denote the amount of imbalance which can be demonstrated by test; that which we are unable to bring out by test is called latent heterophoria.

DIFFERENTIATING ANATOMICAL FROM FUNCTIONAL.

There is no doubt that imbalance, as well as strabismus, is not infrequently due to structural conditions of the eye muscles, both anomalous and pathological; elongated or shortened muscles, tendons which are attached too far forward or too far back on the eyeball, and—most frequent of all—partially paralyzed muscles. And, as it is highly important that the refractionist should know, at the outset, whether he is dealing with an imbalance due to this kind of cause or to one that pertains to a sheer lack of coordination, due to ametropia, it will be well to point out, first, the ways of differentiating between them.

The elemental principle of distinction, upon which all differentiating tests are based, is this: an anatomic defect will show itself in every movement of the eye in which the affected muscle is involved, whereas a purely functional imbalance will be manifested only when the muscle or muscles are engaged in performing the perverted function, i. e., convergence, positive or negative.

The simplest and most obvious test is to have the patient follow with his eyes an object—the operator's finger, a pencil, etc.—as it is moved laterally, vertically, and obliquely, to and fro, without changing its distance from the eyes. If one of the muscles of either eye be structurally weak or insufficient, the movement of that eye will lag as the movement enters the field of the defective muscle, and will lag more and more the further into the field it goes. This will not happen in a sheer case of refractive heterophoria, for eyes that simply fail to coordinate in convergence on account of ametropia perform conjugate movements quite normally.

A further test consists in covering each eye, successively, while the patient fixes an object, preferably at infinity. In both forms of imbalance the covered eye will make a turn, in or out, as the case may be, because the need for fusion is removed; but in functional heterophoria each eye, as it is covered in turn, will make the same amount of deviation, while in organic heterophoria the sound eye will make decidedly the greatest turn when the affected eye is fixing. The reason for this is that the poor eye has to be innervated more strongly

than the good one in order to maintain its fixation, and this extra innervation is imparted also to the covered (good) eye, causing it to exaggerate its deviation.

Duction tests will furnish confirmatory evidence. If, under adduction and abduction tests, one of the eyes shows a marked departure from the 3 to 1 ratio (See **Convergence**) between internal and external muscle, while the other eye shows the normal ratio, it is pretty strong evidence of structural trouble in the short-power muscle.

FUNCTIONAL HETEROPHORIA.

By far the commonest form of refractive imbalance is esophoria, due to hyperopia. It is probable, indeed, that this is the only form which can be attributed directly to error of refraction, since imbalance comes about through accommodation-convergence disruption, and the internals are the only muscles functionally linked with accommodation. In the section on **Convergence** it is shown that exophoria is a normal, inevitable accompaniment of the act of convergence; that most of the cases of refractive exophoria are simply exaggerated manifestations of this accommodative exophoria; and that cases of exophoria which transcend this are usually due to anatomic causes.

ESOPHORIA.

There is no such thing, however, as normal or accommodative esophoria; for there is no normal condition calling for compensatory action of the internals. But in hyperopia, where the patient has to accommodate for infinity, there is an instinctive tendency on the part of the internals to converge in accordance with the degree of accommodation in force. This tendency the patient resists, out of his desire for single vision, and there is thus created a condition of unstable equilibrium, or imbalance, tending inward, known as esophoria. Esophoria is thus the direct result of hyperopia and exactly proportionate to it. Thus, if a patient have 2 D. of hyperopia, he will have 2 meter angles of esophoria, or about 6 prism dioptres, which will be the same at any distance, although it is usually manifested most markedly at infinity.

TESTS FOR ESOPHORIA.

The presence of esophoria can be roughly determined by Duane's test, or the cover test, already referred to, namely, by having the patient fix an object at infinity with both eyes, suddenly covering one of his eyes with a card, in such a way, however, that the operator can still observe the covered eye. If esophoria is present, the covered eye will make a turn inward.

Quantitative estimation of esophoria must be made by means of dissociation tests, a full description of which will be found in the section on **Convergence.** Neither the Maddox rod nor the dot and line test will, as a rule, disclose the full amount of esophoria present, because, in spite of dissociation, the mental faculties of the patient still induce a certain amount of attempt to fuse the images. The patient knows that he is expected to fuse them, and tries to do so. This amount of latent imbalance, however, need give us no concern; for whatever the patient is able to overcome under these conditions will certainly give him no trouble in his ordinary use of the eyes.

EXOPHORIA.

As previously stated, most cases of so-called exophoria at near point, in myopes, are but exaggerated manifestations of accommodative exophoria. The myope uses little or no accommodation at near point; most of his convergence is stimulated by his fusion faculty, and when the fusion sense is destroyed by dissociating the images it is readily released. This condition, in young adults who have not yet become presbyopic, rarely gives any trouble or calls for any aid.

In presbyopes whose accommodation has fallen to, or near, zero the same state of affairs obtains; in them it frequently proves troublesome merely because their fusion faculty easily tires.

Genuine exophoria is practically always due to mechanical or anatomic causes, chief among which is the difficulty of rotating the elongated eyeball. This type of exophoria manifests itself at infinity as well as at near point, and, in most cases, quickly develops into exotropia. Indeed, it may be

remarked that the great majority of apparent exophorias, manifested at infinity, are really slight exotropias.

TESTING FOR EXOPHORIA.

Exophoria is tested and estimated in the same way as esophoria, namely, by dissociation of the images by means of Maddox rod, dot and line, and index pointer, and by prism measurement.

HYPERPHORIA AND CATAPHORIA.

There is nothing either in hyperopia or in myopia to induce vertical imbalance; it may therefore be safely considered that all cases of hyperphoria and cataphoria are due to mechanical or anatomical causes. A misplaced macula is sometimes the cause.

The tests for vertical imbalance are the same as for lateral imbalance. except that the Maddox rod and the chart are to be placed at right angles to the position given them in testing lateral cases; in this way the bar of light made by the Maddox rod will lie horizontally across the visual field, showing the displaced image above or below it, and the apparent displacement of the dot or the index pointer will be up or down the graded line.

Vertical imbalance is spoken of as being right or left, according as it is the right or left eye which deviates upward or downward under the test. However, it can be quantitatively estimated by a prism in front of either eye, as the superior and inferior rectus of the two eyes counteract each other in imbalance.

CYCLOPHORIA.

Occasionally there occur cases of heterophoria in which the oblique muscles play a decided role, so that there is a tendency to rotary imbalance. This condition is known as cyclophoria, and manifests itself under test by an oblique position of the objects viewed. It is corrected by a resultant prism, with the base in the direction of the angular displacement of the image.

An excellent test for cyclophoria is the old cone test. A cone of glass, cemented onto a ground glass disk, is mounted and centered before one eye, the other being meanwhile covered with an opaque disk. Attention is directed to a candle

flame. The cone draws the flame out into a circle of light. The other eye is now uncovered. If there be no imbalance, the candle flame will be seen in the centre of the circle of light. If there be cyclophoria, the flame will be displaced outside the circle, and the direction in which it is displaced will indicate where the base of the correcting prism must be placed.

TREATMENT OF HETEROPHORIA

There is no more disputed subject in the realm of refraction than the treatment of heterophoria. One can lay down only a few guiding rules, or principles, to govern the management of such cases, leaving the details of treatment to be worked out in each individual case.

ESOPHORIA.

Since esophoria is almost always the direct result of hyperopia, it is usually only necessary to correct the hyperopia to remedy the imbalance, especially if the degree of imbalance does not exceed that which is proper to the amount of hyperopia present, i. e. in prism dioptres, three times the dioptres of hyperopia. If it be greatly in excess of this proportion, or if it give much trouble, still an attempt ought to be made to remedy the trouble without resort to prism correction, giving the lens correction plenty of time to assert its influence, and perhaps giving the patient exercises in fusion. If prism correction seems imperative, then a careful examination should be made to determine the least possible amount of prism correction that will enable the patient to maintain fusion, and that amount barely prescribed, so as to keep the fusion faculty in exercise, reducing the prism from time to time as the patient can bear the reduction.

EXOPHORIA.

Exophoria is not so easy to dogmatize about, because it has not the same direct relation to myopia that esophoria has to hyperopia. The rule is to give only two-thirds or three-fourths of whatever exophoria there is at near point in excess of accommodative exophoria. The strong probability is, however, that if it can once be established that exophoria is present other than accommodative exophoria, it will eventually have to be corrected by prisms, and this might as well be done at

once. Certainly, exophoria strongly manifested at infinity usually calls for full prism correction.

HYPERPHORIA AND CATAPHORIA.

As the movements of these muscles are in reality conjugate movements, it is highly probable that all cases of vertical imbalance are due to anatomic conditions, and that prism correction will be found necessary in every instance.

MUSCLE EXERCISES.

As to the value of muscle exercises, by means of prisms and other methods, in cases of heterophoria, there is a wide latitude of opinion. Certainly such exercises must be carried out with great intelligence and caution, for fear of doing more harm than good. This subject will be found discussed under the heading of **Muscle Exercises.**

Heterophorialgia. Pain due to muscular imbalance.

Heterophthalmus. Usually caused by heterochromia of either or both irides, making the two eyes look different.

Heterotropia. When a pair of eyes in which, for any reason, muscular imbalance exists, no longer maintain parallelism or fusion, but take up a more or less permanent position of stable equilibrium with their visual axes either convergent or divergent, this condition of manifest heterophoria is known as heterotropia. It is also commonly known as strabismus, or squint. For a detailed discussion of the subject, see **Strabismus.**

History of Optics. The history of optics, like that of every physical science, is a widely distributed affair, and reaches into remote ages and into every part of the world. Thinkers and workers, of every period, and every race, have contributed to its evolution and upbuilding, from Aristotle down, and it would be impossible, in a work of this limited scope, to give even an abridged account of its history from the beginning.

The modern history of optics, at least so far as the refractionist is concerned, may be said to have its beginning with the discovery by Willebrord Snell, a Dutch astronomer and mathematician, of the law of refraction. Snell was born at

Leiden, in 1591, and succeeded his father as professor of mathematics in the University of Leiden. It was in 1621 that he discovered the law of refraction, that "the ratio of the sines of the angle of incidence and the angle of refraction is constant." His discovery, however, was not published until ten years after his death, when it was announced in a work by Descartes, without any reference to Snell's name, in 1635. Whether Descartes had access to Snell's manuscript, or made the discovery on his own part, is a disputed question.

Snell's original manuscript did not set forth the law in the form in which we now state it. It expressed it as the ratio of certain lines trigonometrically interpretable as sines of cosecants. Descartes expressed the law in its modern trigonometrical form, i. e. as the ratio of the sines of the angles of incidence and refraction.

In his work on the system of nature, Descartes developed a theory of light which in some respects resembled the old Aristotelian theory and in some respects approximated the modern wave theory. He regarded light as a pressure, transmitted by an infinitely elastic medium, and color as being due to rotary movements of the particles of this medium. He attempted a mechanical explanation of refraction, and held that the more highly refractive the medium the more readily light passed through it. His views were opposed by Pierre de Fermat, who argued that, since Nature performs her operations by the shortest possible paths, the path traversed by a ray of light between two points must be such that the time occupied is a minimum. This law he termed the "law of least time." He pointed out that the linear propagation of light and the law of reflection agreed with this principle, and that the law of refraction would probably be found to correspond with it. While his premises were wrong, his conclusions were right, and led to Sir William Hamilton's conception of "characteristic function" by which all optical problems are solved.

Up to 1676 the velocity of light propagation had been regarded as infinite. In that year, Ole Roemer, a Danish astronomer, born in 1644, and later Astronomer Royal to the Copenhagen observatory, deduced the finite velocity of light from a comparison between observed and computed times of

the eclipse of the moons of Jupiter. This velocity he calculated as 186,000 miles per second, in luminous ether.

In 1678 Christiaan Huygens, a Dutch physicist, enunciated his famous theory of the undulatory nature of light, upon which all of our modern science and art of refraction are based (see **Light**). For many years this theory of light was overshadowed by the corpuscular theory of Newton, owing to the tremendous authority of the English mathematician. Not until the early part of the nineteenth century did the corpuscular theory meet any serious opposition. Its chief opponents were Thomas Young, Fresnel, Neumann, Green and Stokes; but it was J. B. L. Foucault who finally overthrew the Newtonian doctrine and established Huygens' wave theory by showing that the velocity of light was less in water than in air.

Meantime, the evolution of the scientific and philosophic aspects of optics was accompanied by a corresponding progress in the material side of the subject, i. e. in the invention and manufacture of optical instruments. The grinding of spherical lens surfaces was greatly improved by Huygens, who also did considerable work, but without much result, upon the production of an achromatic lens. Not until 1757 was this object achieved by John Dollond, an English optician, born in 1706, originally a silk weaver of Spitalfields, London. He first made an achromatic lens by a combination of glass and water media, and then succeeded in accomplishing the same end by combining different densities and qualities of glass.

In 1784, Benjamin Franklin, on this side of the Atlantic, invented bifocal lenses; and in 1837 Schnaitman took out a patent on one-piece lenses, in which the distance and the reading portions of the lens were ground upon one piece of glass.

In 1844 the theory and mechanics of lenses experienced an epoch-making impetus in the work of Karl Freiderich Gauss, the distinguished German astronomer and mathematician, who was born in 1777. Gauss' work, in determining focal points and image representations, was in later years supplemented by that of E. Abbe, and by Listing, who in 1845 demonstrated nodal points.

In 1855 the ophthalmoscope was invented by Hermann Ludwig Ferdinand von Helmholz, the German physicist and

physiologist, who was born in Potsdam on the 31st of August 1821. In 1871, Cuignet invented the retinoscope, which, of course, is an application of the principle and method of the ophthalmoscope. Helmholz also devised the principle of the ophthalmometer, for measuring the curvature of the cornea; and he constructed an ophthalmometer, but for many reasons it was not a practical success. The first practicable instrument was built in 1882 by Javal, which constitutes the model of our modern instruments.

One of the latest achievements in technical optics is the invention and construction of lenses of such composition as to prevent the passage of the ultra-violet and other rays. This was accomplished in 1912 by Sir William Crookes, the English physicist who devised the first tube for developing the X-ray, and the lenses are called by his name.

In the development of the clinical side of optics—physiologic optics, three names stand out so far above all the rest that they may be mentioned without any fear of rivalry,—Helmholz, Young and Donders.

Helmholz has already been mentioned as the inventor of the ophthalmoscope. He is also responsible for invaluable work in the physiologic field of optics, notably for a demonstration of the function of accommodation, and the formulation of a theory of its mechanism which dominates the field of teaching to the present day, and the joint enunciation with Young of a theory of color-perception, which will be found discussed in its proper section.

Thomas Young was an English physicist, born at Milverton, Somersetshire, of a Quaker family, in 1773. He anticipated Helmholz by several years in a general explanation of the mode by which the eye accommodates itself to vision at different distances by changing the curvature of the crystalline lens. He originated the theory of color perception which Helmholz afterwards developed. He was, moreover, the discoverer of the phenomenon of the interference of light waves.

Frans Cornelius Donders was a Dutch physician, who was born in 1818 at Tilburg, Holland, and afterward became Professor of Physiology, Histology and Ophthalmology in the University of Utrecht, where he himself had been educated.

He was contemporary with Helmholz. He did a tremendous amount of important work on ocular refraction, especially in regard to the physiology of accommodation and presbyopia, and enunciated some laws governing these phenomena (See **Laws**). To Donders, in fact, we owe most of our modern knowledge of the subject, and he may well be called the father of modern refraction.

In the last fifty years, and especially in the last twenty-five years, optics has made enormous strides, both as a science and also as a profession, and the number of able men that have contributed to its progress is legion. However, in this more recent period very few, if any, really basic principles have been discovered, or fundamental innovations made.

Hippus. Iridodonesis; spasmodic movements of the iris.

Hippus, Respiratory. Dilation and contraction of the pupils, in rythm with inspiration and expiration, respectively.

Hirschberg's Method. Using reflection of a candle from the cornea to measure the amount of deviation of a strabismic eye.

Holmgren's Test. A test for color blindness. See **Color Blindness.**

Holocain. A local anesthetic drug, often used in the eye, either in place of, or in combination with, cocaine. It is four times as anesthetic as cocaine, non-toxic, does not affect the cornea (as cocaine does), and is soluble in 40 parts of water.

Homatropine. A mydriatic agent, much used in the eye where it is desired to obtain a temporary dilatation of the pupil or suspension of accommodation for purposes of examination. Its effects wear off in about 18 to 24 hours. It is commonly used in a 2 per cent solution, a drop being put into the eye every four or five minutes for an hour. Good dilatation is then present.

Homocentric. Seeking a common centre. As applied to light this implies that the rays have been rendered convergent by a mirror or a lens that is a segment of a sphere, so that they are converging, in the form of a cone, to one focal point.

Homogeneous. A body is said to be homogeneous whose substance is of the same physical character and properties throughout. Such a body, of course, has a uniform effect upon any form of energy (as light) which passes through it as a medium. Optical glass is homogeneous.

Homogeneous Immersion. A method in microscopy in which the object to be viewed and the objective lens are both immersed in a continuity of oil of the same optical density as the lens, thus increasing the magnifying power of the latter.

Homonymous. Like, or corresponding. Applied especially to diplopia in which the images separate in the same direction as the eyes that see them, and to half-blindness of corresponding halves of the retinae.

Hordeolum. Stye. Infection of hair follicle of the lid. Successive crops of styes are often due to eyestrain from errors of refraction.

Horny Epithelium. Hard, hypertrophied state of the epithelium, such as is often seen in the conjunctiva in trachoma.

Horopter. The area included in the field of binocular vision. See **Binocular Vision.**

Hot Eye. A temporary congestion of the eye, frequently met with in gouty subjects.

Humor. Fluid content of the chambers of the eye. The aqueous humor fills the anterior chamber; the vitreous humor the portion of the eye back of the lens.

Hutchinson's Pupil. Unilateral dilation of the pupil.

Hyalitis. Inflammation of the vitreous.

Hyaloid. Literally, resembling glass. It is applied to anything which pertains to the vitreous.

Hyaloid artery. Branch of the central retinal artery which in the fetus pierces the vitreous for its nourishment.

Hyaloid canal. The canal through which hyaloid artery passes. The canal persists in extra-uterine life. It is also called the Canal of Stilling.

Hyaloid Fossa. The depression in the anterior surface of the hyaloid membrane into which the crystalline lens is set.

Hyaloid Membrane. The membrane surrounding the vitreous, and forming the suspensory ligament and zonula.

Hydrophthalmia. Increase in watery fluids of the eye.

Hygiene of the Eye. So far as the visual function is concerned, the hygiene of the eye falls into two general divisions, namely, (1) that which pertains to the muscle elements, accommodation and convergence, and (2) that which has to do with the retina, to which may be added (3) that which concerns the ordinary care of the eyes themselves.

(1) MUSCULAR HYGIENE.

Close Application. Where continued contraction of a muscle or a group of muscles is maintained for long periods in carrying out work upon which the attention is fixed, the sense of fatigue does not manifest itself until a rest is taken, or until the muscles give out and refuse to contract longer. This is precisely what takes place in the ciliary and internal rectus muscles of the eye when the vision is concentrated at near points for any considerable length of time. In addition, the continued and excessive demand of the muscles for blood during their activity induces congestive troubles in the eyeballs and eyelids.

Frequent Rests. For these reasons the vision should not be exercised continuously at near point. Persons whose occupation obliges them to work at close range should make a practice of giving their eyes frequent short rests by removing them from their work and relaxing their accommodation and convergence for a few minutes by looking into the distance.

Children's Eyes. The mischievous results of continued maintenance of close vision are particularly marked in young children, whose musculature is in the formative stage. Fortunately we are nowadays waking up to the dangers of this abuse, and are taking steps to avoid them.

Children should not be required to decipher very small or close characters at all. Their books should all be printed in moderately large and very plain type, and held at a proper

distance from the eye. And, in the second place, their tasks should be arranged so as to give them the least possible amount of close work, and the greatest possible alternation of work requiring no visual effort.

All of the above-mentioned evils of close application, both in children and in adults, are of course intensified a hundred-fold when any error of refraction exists.

(2) RETINAL HYGIENE.

Poor Illumination. Near work done under poor illumination has precisely the same ill effect as that which is done under conditions of excessive exactingness. The inadequate intensity of the image on the retina requires that the image be held there for a greater length of time in order to make the proper impression on the brain. Thus the musculature and the central nervous system both suffer. The question of what constitutes inadequate illumination will be found discussed in the section on **Illumination.**

Excessive Illumination. Too much light is almost, if not quite, as bad as too little. A moderate degree of irritation of the retinal nerves by light is necessary to the production of sensation of vision; but if the stimulation be too vigorous, the nerve-ends of the retina quickly become inflamed or exhausted, and retinitis or retinal asthenopia ensues. Besides, bright light is rich in ultra-violet actinic rays, which are harmful to the retina. Facing continuously a bright window, or doing one's work by a hard, brilliant light should be avoided; and if one's employment makes such practices unavoidable, then he should wear tinted glasses to protect the eyes.

Glittering Materials and Colors. A frequent cause of this type of eye-strain is the excessive reflection and scintillation of light by the object upon which one is working. Printers and metal workers experience this kind of trouble. The only efficient prophylaxis is to wear tinted glasses, and to take frequent short periods of rest.

Those who are obliged to concentrate their eyes upon one or more bright colors suffer not only from general retinal exhaustion, but from a specific exhaustion of these elements which respond to the colors in question. Their only means of relief

is the wearing of tinted glasses of such a color as to neutralize the offending color into a more or less mixed and quiet tint. Failing this, they must rest the fatigued retina by gazing frequently at the color which is complementary to the one which distresses them.

(3) CARE OF THE EYE ITSELF.

Dust. A common source of eye trouble, especially in large cities, and in these days of the automobile, is in the dust that enters the eye and irritates the conjunctiva. It is a frequent cause of conjunctivitis and pterygium. The only effective safeguard is the wearing of goggles, to which the ordinary man or woman can hardly be expected to submit. Those who are in the dust a great deal should wash their eyes every evening with a copious irrigation of boric acid solution.

Cold. The membrane of the eye is subject to the same ill results of sudden and extreme changes of temperature as other membranes of the body. It is able to adjust itself to moderate variations, but violent changes, especially when accompanied by high winds, will congest the conjunctiva and induce conjunctivitis. When facing an extraordinarily severe cold or heat the lids should be kept closed for a few minutes until the conjunctiva becomes gradually accustomed to the change. In cases of very extreme exposures, of course, goggles should be worn.

Infection. The conjunctiva has a very ready and rapid absorptive capacity, and presents a most facile field for invasion by infectious material of all kinds. Scrupulous care should be exercised at all times to avoid this kind of injury. Whenever it is necessary to manipulate the eye or eyelids the hands should be carefully washed; if a handkerchief or cloth is used, it should be scrupulously clean; any drops or wash for the eyes should be prepared with sterile water; and after any such manipulation the eye should be thoroughly flushed with warm boric acid or other mild disinfectant solution.

Such precautions are especially important in the case of persons suffering from an infectious disease in other parts of the body, especially if accompanied by a discharge. If habits of carefulness be formed during times when there is no emer-

gency, they will be exercised automatically when emergencies exist.

Posture. Posture has a powerful influence upon the health and development of the eye. Poring over a book with the head bent almost to the knees, so common among children, induces general congestion of the eyeball, overproduction of secretions, stretching of the choroid, bringing about choroiditis and progressive myopia by elongation of the eyeball. Myopes are particularly guilty of this habit.

All persons, and especially myopes, in reading and close work, should form the habit of sitting upright and holding their work at a comfortable distance from the eyes. If their refraction will not permit them to do this it should be corrected so as to enable them to do it.

Hyoscine. An alkaloid of hyoscyamus, sometimes used as a mydriatic.

Hyperemia. Congestion of the blood vessels. This condition is seen in all infections and inflammations of the eye.

Hyperesophoria. Condition arising from muscular insufficiency causing one eye to deviate upward and inward.

Hyperesthesia. Exaggerated reaction to stimulus.

Retinal hyperesthesia. Excessive sensitiveness to light.

Hyperexophoria. Condition arising from muscular insufficiency causing one eye to deviate upward and outward.

Hyperkeratosis. Hypertrophy of the corneal tissue.

Hypermetropia. See **Hyperopia.**

Hyperope. A person who has hyperopia.

Hyperopia. That condition of refraction in which the posterior principal focus of the eye lies back of the retinal plane, so that neutral light waves, instead of focussing on the retina, fall on the retina in diffusion circles of unfocussed waves. In other words, the focal length of the refracting system of the eye is greater than the antero-posterior diameter of the eyeball.

The only kind of light wave that, falling on the cornea, could focus upon the retina of a hyperopic eye at rest, would be a convergent wave; and this wave would have its source of origin beyond infinity. This is equivalent to saying that the far point of a hyperopic eye lies beyond infinity. There is, however, no way of measuring or expressing a linear distance beyond infinity. We are therefore reduced to the necessity of defining the hyperopic far point in terms of the reciprocal of the convergent light wave that is normal to the eye at rest.

Further, such a wave could not have its source of origin in nature, since all light waves in nature are divergent. Nor can such a wave be measured, as to radius and curvature, from its imaginary point of origin; first, because there is no such point in space as "beyond infinity," and second, because a convergent wave does not travel from a point at all, but to a point. Its radius and curvature, therefore, must be determined in relation to the point (back of the eye) to which it is converging.

Thus, if we assume an eye to be 2 D. hyperopic, such an eye at rest could focus upon its retina only a light wave which, when it falls upon the cornea, has a minus curvature of 2 D., i. e. is 2 D. convergent. Such a wave would have a radius of 50 cm. So we say that the far point of this eye is 50 cm. beyond infinity; but this, of course, expresses simply the convergence of the wave proceeding from the eye's far point. Or, we may say that the far point lies 50 cm. back of the cornea; which signifies the same thing.

Clinically the hyperopic far point is determined by the methods which have already been described in the chapter on Accommodation, that is to say, subjectively by means of the Snellen type-chart, objectively by means of static retinoscopy.

If the patient is able to read No. 6 type at 6 meters, or No. 20 at 20 feet, we conclude that he is either emmetropic or else hyperopic. A myope could not read this type at this distance, his far point being inside of infinity. If he is an emmetrope, he is reading 20/20 with his eye at rest, i. e. with no accommodation in force. If a hyperope, he is using some accommodation to read it. To determine which of these two possibilities is the actual state of affairs, we place before the patient's eye

a weak-power convex lens, say a plus .50. This makes the light waves falling on the patient's cornea slightly convergent. If he be an emmetrope, with his ciliary already relaxed to the limit, he has no way of adapting his eye to these slightly convergent waves, hence the 20/20 type blurs. But if he be a hyperope, reading 20/20 with some of his accommodation in force, he can readily adapt his eye to the slightly convergent waves by simply relaxing .50 D. of his accommodation. The plus .50 D. lens, therefore, will not blur the type; and the amount of plus power we can add to his eye without blurring 20/20 will represent the amount of his hyperopia and render him normal.

Objectively, we place a plus lens before the patient's eye and with our retinoscope find the point of reversal. In hyperopia, with the ciliary relaxed, we shall always find this point of reversal further from the eye than the focal length of the plus lens employed. The difference between the place where it ought to be and the place where it is, in terms of dioptrism, gives us, also in terms of reciprocal, the patient's far point.

Thus, with a plus 2 lens we find the point of reversal at 1.50 meter. It ought to be at 50 cm. The formula will be:

$$\frac{1}{.50} - \frac{1}{1.50} = \frac{1}{75}$$

That is to say, the patient's far point is 75 cm. beyond infinity, and he is 1.33 D. hyperopic.

SOURCES OF ERROR.

If in these two procedures everything worked out as clearly in practice as it does on paper, no further demonstration would be needed of the patient's hyperopia or of his distance correction. Unfortunately, however, such is not the case. There are usually complicating factors which vitiate the validity of these simple tests, chief among which is the existence of a ciliary spasm.

By dint of long-continued use of his accommodation at infinity the hyperope often develops a permanent contracture of the ciliary muscle which locks his accommodation at that point, so that he cannot relax and release it. Such a patient can read 20/20, but on the addition of a weak plus lens he is

unable to give up any of the accommodation with which he was reading the 20/20, and the lens blurs his vision. Under these circumstances he is quite likely, under the subjective test, to be mistaken for an emmetrope. Occasionally a hyperope who works habitually within a range less than infinity will develop a spasm which locks his accommodation at a point nearer than infinity, in which case he cannot read 20/20, and behaves like a myope.

The same condition of affairs will, of course, vitiate the objective test with the retinoscope. With the accommodation locked at infinity, the point of reversal is found at the focal length of the objective lens, simulating emmetropia. When locked at a point within infinity, the point of reversal is found inside the focal length of the lens, simulating myopia. This latter condition, known as "false myopia," has not infrequently led the practitioner to prescribe minus lenses for a hyperope.

THE FOGGING SYSTEM.

Various plans have been devised for dealing with this situation and avoiding the source of error which it involves. The effectiveness of these devices rests upon one of two principles of action—either they must force the patient to surrender his spasm, or they must measure and reckon with the amount of the spasm.

Subjectively, the most commonly used method is what is known as the "fogging system," which consists in placing before the eye a strong plus lens, which renders the patient highly myopic, and leaving it there for a while. In his effort to see through this lens, the patient is induced to make extraordinary effort to relax his ciliary; and in cases where the spasm has not become absolutely fixed this plan often succeeds in inducing a relaxation. In testing with the Snellen chart, the strong plus lens is left in position, and gradually reduced with minus power until the patient reads 20/20.

Valuable as this procedure is, it still leaves us, at the conclusion, uncertain as to whether all the spasm has been released. Many practitioners, however, content themselves with the outcome of the fogging test for the prescription of initial distance correction, and trust to the wearing of these glasses

to presently break up the remainder of the spasm, so that the patient may at some future time be given his full correction.

The fogging system, as applied to skiascopy, is substantially the same in principle and technique. Plus spherical power is put in front of the eye under test until it is fogged; then minus spheres are used until the shadow is abolished. To make sure the point of neutralization has not been passed, the observer draws back a trifle to see if the motion is then against the mirror. With this method the distance of the fixation object is immaterial. It need not be at infinity. The patient may look at a line of letters on the retinoscope, the same as in dynamic skiacopy, but as long as he is fogged his eyes will relax fully.

THE HYPEROPE'S ACCOMMODATION.

The mere determination of the far point, however, no matter how accurately it be done, is but a small part of the practical problem of the refraction and correction of hyperopia. The crux of the hyperope's condition and treatment is the state of his accommodation and its relation to his convergence.

The first thing to be ascertained is the patient's available amplitude of accommodation, which, as previously set forth, (see **Accommodation**) is to be arrived at by finding his near point and subtracting the far point from it in terms of dioptrism. There are, as we have seen, two methods of determining his near point—subjectively by means of the Jaeger type charts, and objectively by dynamic skiascopy. In the former test we find the nearest point at which the patient can read the type of appropriate size for the distance in question—i. e. as we move the card in from 75 cm. to 50 cm. we must shift the patient's attention from the .75 type to the .50 type, and so on. In the latter test, with the patient's vision fixed on the type at the top of the retinoscope, we find the point of reversal.

If there is no spasm present—or none but what the patient readily surrenders—the subjective and objective findings will approximately coincide. If there be considerable discrepancy between them—the objective near point being considerably closer in than the subjective—it is generaly considered that the difference represents the amount of latent hyperopia present—

although many excellent authorities dispute this. At all events, whatever may be the precise connotation of the discrepancy, it seems to be pretty well established by clinical experience that the showing of a marked discrepancy indicates the existence of a spasm.

Where no discrepancy shows—where the subjective and objective near points approximately coincide—the case is comparatively simple. The hyperopia is wholly manifest and the relation between accommodation and convergence is probably normal—i. e. normal to the amout of hyperopia. The difference between the demonstrated far point and the demonstrated near point, in terms of reciprocals, represents the available amplitude of accommodation; and if this amplitude be what one would expect at the age of the patient, the case is one of clear sailing.

Thus, if we find the far point to be 50 cm. beyond infinity, and the near point, both by subjective and by objective test, to be at 12.50 cm., in a patient 35 years of age, then, according to the formula:

$$\frac{1}{12.50} - \frac{1}{.50} = \frac{1}{16.66}$$

the patient's amplitude of available accommodation is 6 D., which, at the age in question, is normal. This patient is 2 D. hyperopic, and a correcting lens of 2 D. ought to be satisfactory.

It is seldom, however, that a case of hyperopia works out with such nicety. Continued over-use of the accommodation and suppression of the convergence have practically always set up a vicious circle of troubles in and between these two functions.

ACCOMMODATION-CONVERGENCE RELATION.

It has already been stated that accommodation normally stimulates the act of convergence; and, as the hyperope is obliged to accommodate for objects at infinity, he is stimulated to exercise his convergence to the extent of his accommodation. This, however, he may not do under penalty of double vision. He is therefore put to the necessity of suppressing his convergence.

Whether he suppresses it in potentia or in esse, i. e. whether he suppresses the desire to converge and withholds the innervation from his internal rectus muscles; or whether the internal recti are innervated to contraction and then counteracted by an equal innervation and contraction of externals; is a question that cannot be definitely answered. The probability is that in some cases the former course is followed while in others the latter.

It is a well-recognized fact that patients with low and moderate degrees of hyperopia suffer more, as a rule, from headache and asthenopia than those with high degrees of error. These can hardly be ciliary symptoms; if they were, the reverse would be the case, for high hyperopes over-work their ciliaries more than low hyperopes. Most likely the low-degree and high-degree hyperopes choose different ways of dealing with the accommodation-convergence disturbance, the former yielding to the accommodation stimulus to convergence and counteracting it with their external recti, (hence their muscular symptoms) the latter suppressing the stimulus altogether and presently learning to ignore it.

In either or any case the hyperope holds his convergence—or, rather, his parallelism at infinity—as a condition of unstable equilibrium, in virtue of his desire for singleness of vision; and every hyperope has a potential esophoria (whether he manifests it or not) normal to his hyperopia, i. e. of the same meter angles as the dioptres of his error, or approximately three times as many prism dioptres.

Such a state of affairs is morally bound, sooner or later, to produce a serious disruption of the coordination between accommodation and convergence, resulting not so much in an insufficiency as in an inefficiency of both functions. The positive relative accommodation is diminished; relative convergence is exaggerated; and manifest esophoria is almost certain to ensue. Near vision is therefore the bete noir of hyperopia, and, as previously stated, the correction of distance vision is usually but a small part of its treatment. The accommodation-convergence relation calls for the most searching investigation.

EXAMINATION.

The procedure to be followed in the examination of a hyperope, then, may be outlined as follows:

1. Determine the far point subjectively, by means of the Snellen chart, preferably by the fogging method, reducing the high plus power by means of minus spheres until 20/20 is read. The net plus power before the eye at this point, divided into unity, represents the distance of the far point beyond infinity.

N. B. The wheel chart should be introduced into this test as we go along, for the purpose of detecting or excluding astigmatism. The necessity of watching for astigmatism applies to every form of procedure.

2. Fix the far point by static retinoscopy, either by adding plus neutralizing power until the "with" shadow is abolished, or by first fogging with strong plus lens and then reducing with minus power until the "against" movement is neutralized. The net result of this static retinoscopic test should correspond with the subjective finding.

3. Find the near point by means of the Jaeger test type.

4. Check the subjective finding of the near point by dynamic skiascopy, i. e. find the point of reversal with the patient's accommodation fixed on the type attached to the retinoscope.

The near point, divided into unity, gives the total amount of accommodation, from which the reciprocal of the far point must be subtracted in order to determine the available accommodation.

If the findings of tests Nos. 1, 2, 3, and 4 approximately agree; that is to say, if the subjective and objective far point and near point are substantially the same; and if the amplitude of available accommodation which they yield is normal to the patient's age; then the probability is that we have to do with a case of simple, uncomplicated hyperopia, which proper distance correction, to be worn constantly, will adequately remedy.

If, on the other hand, the findings do not coincide; if the subjective and objective far point and (more particularly) near point show marked discrepancy; and if the available accom-

modation is below normal; then it is almost certain that the accommodation-convergence relation is seriously deranged, and we must proceed to investigate this relation by the following further steps:

5. Test out the relative accommodation, positive and negative, by the gradual addition of plus and minus lenses, respectively, while the patient maintains his convergence at a point, say, 33 cm. distant. Normally, he should be able to tolerate 2 or 3 dioptres each way and still be able to read.

6. Determine the "comfortable near point" by means of Lockwood's cross-cylinder test.

7. Make an adduction and abduction test at infinity by means of prisms, base out and base in, respectively.

8. Make a muscle test for imbalance at infinity, by means of the Maddox rod.

9. Make a test for muscle imbalance at 33 cm. by means of the double line and index pointer.

Details of the technique of all the above tests, with ample illustrations, will be found in the chapter devoted to this purpose; and a discussion of their significance will be found in the sections to which they belong, i. e., the accommodation tests in the chapter on Accommodation, muscle tests in the chapters on Convergence and Heterophoria.

Briefly summarized, test No. 5 should show 3 to 5 dioptres of positive relative accommodation and 2 or 3 dioptres of negative. Test No. 7 should show a ratio between the adduction and the abduction powers of approximately three to one. Tests Nos. 8 and 9 ought not to reveal any greater degree of esophoria than is normal to the amount of hyperopia, i. e., approximately three times as many prism dioptres of esophoria as there are dioptres of hyperopia. Indeed, it ought not to disclose as much as that, for a patient rarely manifests all of his esophoria. And the amount of esophoria should register about the same at infinity and near point.

TREATMENT.

If, as will probably happen, the results of the above tests disclose marked abnormalities, the situation will call for the nicest judgment of the practitioner. So far as distance correc-

tion is concerned, the matter is comparatively simple. The hyperopic patient should be given as much plus correction as he will tolerate, for constant wear. The question of near vision constitutes the crux of the problem. No set rules of thumb can be laid down for its solution. Each case is a law to itself. Only a few very general principles can be enunciated for guidance in shaping one's course.

The blanket principle which governs in the management of all cases is that the need of interference depends upon the degree of flexibility shown by the patient's functional mechanism, and his ability to control it.

One of the elemental conditions of flexibility is an adequate reserve. Here, then, is a starting place from which to reach a decision in each case. The most extreme and obvious exemplification of this working principle is seen in a case where the patient's amplitude of accommodation is just sufficient to compass the point at which he wishes to do his near work. In such a case there is no reserve at all at that point; positive relative accommodation is zero; there can be no flexibility; accommodation and convergence cannot coincide at the point in question; nor can the patient hold such a near point. It is clear that in a case of this kind we shall have to supply enough lens assistance to release the patient's accommodation to a sufficient amount to restore something like a normal ratio between amplitude, near point and reserve. And the working principle is the same in less extreme cases.

The adjustment of the reserve, however, by no means disposes of the problem. There are more cases of accommodative inefficiency than of insufficiency. Many patients whose amplitude and reserve are normal—or have been rendered so by lens aid—are still unable to "make ends meet," so to speak, and to achieve a comfortable co-ordination between accommodation and convergence at the point at which they must work. This is probably the most important part of the problem in every case of hyperopia, and on its successful outworking depends the satisfactory fitting of the eyes. We have already discussed this matter fully in the chapters on Accommodation

and Dynamic Skiascopy, respectively, to a careful perusal of which we refer the student.

Hyperphoria. Muscular imbalance in which the eye tends to turn upward. (See **Heterophoria.**)

Hyperplasia. Excessive tissue formation.

Hypertension. Excessive tension. Specifically used to indicate high blood pressure.

Hypertrophy. Abnormal increase in the size of an organ.

Hypertropia. Squint in which one eye turns upward.

Hyphemia. Extravasation of blood into the eye.

Hypometropia. The opposite of hypermetropia, i. e., myopia.

Hypophasis. Eyes half shut, only the whites being disclosed.

Hypophoria. Muscular imbalance downward. See **Cataphoria.**

Hypopyon. Pus in the anterior chamber.

Hyposcleral. Under the sclerotic coat of the eyeball.

Hypotonia. Decreased intra-ocular tension. Also written **Hypotonus** and **Hypotony.**

Hypotropia. Deviation of the axis of one eye downward.

Identical Points. Corresponding points in the two retinae on which rays from an object fall, producing single binocular vision. See **Binocular Vision.**

Illaqueation. Treatment of ingrowing lashes by drawing them with a loop.

Illumination. All the plans and devices that ever have been or ever can be propounded for the best lighting of rooms resolve themselves into the basic principle that light is for the purpose, not of calling attention to itself, but of revealing objects. The whole problem of lighting consists in attaining a light

that shall obtrude itself least upon the eye and at the same time disclose the objects to be viewed with the greatest possible clearness.

The application of this principle necessarily implies the reflection of the light from the object to the observer's eye. Its working out, therefore, involves the consideration of two features: (1) the source and nature of the light, and (2) the course to be traversed by the light from its origin to the object and thence to the observer. All questions concerning the light come under the head either of its illuminating qualities or of its propagation.

Diffusion. In fulfillment of the requirement that light shall attract as little attention as possible to itself, it is essential that it be as diffuse as possible. Daylight (but not direct sunlight) is the ideal illumination, in spite of all the foolish assertions to the contrary, and it should be admitted to the room in such a way as to render its distribution as diffuse and as uniform as possible.

Daylight being inaccessible, or for any reason undesirable, the next best substitute is the indirect system of lighting in which the light is reflected from the ceiling and walls of the room. After that, the next best is a white or slightly yellow artificial light surrounded by a spherical globe of frosted glass for the purpose of diffusion. The globe need not be a complete sphere, for it is rarely necessary to direct light upward, but it should be of a spherical curvature, so as to give uniform diffusion. Uniformity of distribution is best attained by a uniform distribution of the sources of light throughout the room, rather than grouping them in the center. This must of course be done with due regard to the matter of intensity and of the purposes for which the room is to be used.

Intensity. The intensity, or what the layman calls the strength of the light, is a matter whose adjustment depends upon the purpose for which it is wanted, and one in which the most absurd paradoxes are perpetrated in actual practice. One does not require as much intensity of light for a dancing party or a reception as for reading or sewing; yet as a rule the danc-

ing hall or reception room is lighted far more brilliantly than the reading or sewing room. Too great intensity of light is injurious to the eyes by reason of its exhausting effects upon the retina, and also because it reveals more detail than is necessary and thus induces nagging eye-strain. Too little intensity, on the other hand, is harmful because it necessitates closer application.

It is estimated that for ordinary visual purposes, e. g., for a dining or reception room, an intensity of 32 candle power per 1000 cubic feet of space is about right, while for close work it should reach 64 candle power per 1000 cubic feet.

Modes of Lighting. As stated, daylight is easily the most desirable mode of light. In addition to its other superiorities, it has the advantage of furnishing white light, which is most conducive to visual acuity. Its chief disadvantages are its unreliability, short duration, and the difficulty of admitting it in sufficient quantities.

Artificial modes of light are desirable in proportion as they approximate the advantages of daylight and compensate for its disadvantages.

Electric Light. The mode of artificial light which comes nearest to fulfilling these conditions is undoubtedly the electric incandescent light. It gives an almost white light; it burns with comparative steadiness; it yields the greatest degree of intensity for the least bulk; its intensity is most easily measured and regulated; it does not vitiate the air; does not affect humidity or temperature to any marked extent; and it carries no danger of fire. Incidentally it may be added that it is the most economical light, both in respect of production and of physical health.

Gas. Next to the electric light, illuminating gas, with some form of mantle burner, is most desirable. By means of these burners much of the objection to the color and unsteadiness of the flame is overcome. There still remain, however, the objections of vitiating the atmosphere, raising temperature, lowering humidity, and risk of fire, to which may be added the difficulty of obtaining a good grade of gas. Acetylene is better than coal gas.

Oil Lamps. In the absence of facilities for electric light or gas, one must, of course, use oil lamps. They are very undesirable things at best, and all one can do is to reduce their objectionable features as much as possible, by employing a high grade of kerosene, i. e., one with a high flash point, a well-made air-tight lamp, a good circular wick, and a first-class chimney surrounded by a white opaque globe. An ordinary sized room will require two or three such lamps, of large size, to light it adequately.

Position of Light. The object to be viewed,—the book to be read, for example,—should not be between the person and the source of light; in fact, the source of light should not be in front of the observer at all. For a light in front calls attention to itself, exhausts the retina, is not reflected from the object and therefore does not illumine it, and in the case of writing or sewing casts a shadow toward the worker—in all of which it violates the canons of good illumination.

It is equally evident that the source of light should not be immediately behind the observer, for then his own body will intercept the light so that it cannot reach the object, and all the room will be illumined except the very portion where illumination is desired.

The source of light directly to the side of the observer is almost as bad as directly in front; for in this position the rays strike the object at an extremely oblique angle, and are reflected at an equally oblique angle to the other side; many of them pass laterally between him and the object. In addition to these faults of reflection, the light strikes his eye at a lateral inclination, which is peculiarly irritating, as everyone knows who walks sideways to the sun when it is just going down.

The Correct Position. The most satisfactory position for the light is midway between the rear and the left lateral. In this position the light falls on the object at a slightly oblique angle which just reflects it into the observer's eye, and no shadow is cast between the observer and the object. The right lateral is not quite so good a position, because in most persons the right eye is the dominant eye.

Influence of Position on Intensity. In arranging such a position, the light must not be too far from the object to illumine

it in sufficient detail, or so near as to unnecessarily exaggerate detail and tire the retina.

Influence of Position on Diffusion. The same remarks apply to the diffusion of light. If the source of light be too near the object, the light will not be sufficiently diffused by the time it reaches it; if, on the other hand, it be too far away, diffusion will be so great as to weaken intensity and reflecting power.

What has here been said concerning the position and distance of the source of light applies equally to windows transmitting daylight and to artificial sources of light.

Illumination, Ophthalmic. The different methods of illuminating in ophthalmology are as follows:

Axial illumination. When the light is transmitted along the axis of a lens, or reflected along the axis of a mirror.

Direct illumination. When the light is thrown directly on to the object.

Focal illumination. When the light is focussed on the object by lens or mirror.

Oblique illumination. When the light is passed obliquely through a lens and made to fall on one side of the object.

Image. An optical image is formed by the reuniting of waves of light from an object, by means of a lens or a mirror, in a series of foci identical in arrangement and quality with those from which the light proceeded. The area occupied by this group of foci, i. e., the size of the image, has nothing to do with its accuracy.

The only kind of mirror or lens that can produce an accurate image is a spherical one; all others distort the contour of the image. Furthermore, every real image is inverted, because the nodal point of a spherical focal system, where the axial rays cross, always lies in front of the focal point.

Indistinct, what may be called near-images, are formed by waves that are almost focussed. Strictly speaking, from an optical standpoint, these are not images at all; but physiologically, if the waves are focussed nearly enough to produce the required reaction in vision, we call the reaction an image.

The size of an image depends upon its distance from the focussing lens or mirror. Its size, as compared to that of the object, is in direct ratio to its distance from the lens or mirror, as compared to that of the object.

For further details of images and their optical relationships, see **Lens.**

Aerial Image. One that is formed in the air, such as we see in indirect ophthalmoscopy. Such an image is not really seen, as images are only visible through the intervention of a screen. An aerial image becomes an object, which is again imaged on the retina, and the retinal image perceived.

After-Image. See **After-Image.**

Chiasmal Image. See **Chiasmal Image.**

Cyclopic Image. The single image of one's eye which one sees when looking stereoscopically into a plane mirror, i. e., with each eye fixed upon the corresponding eye in the mirror.

Direct Image. Same as an upright, or virtual image.

Erect Image. Same as a virtual image.

False Image. The image made upon the retina of a deviating eye in strabismus or diplopia.

Indirect Image. Same as an inverted image.

Real Image. An image produced by the actual focussing of light waves from an object by means of a convex lens or a concave mirror. Such an image is inverted, because the focal point is always posterior to the nodal point.

Retinal Image. The representation of an object formed upon the retina by the focussing of rays from the object at the retinal plane. Being a real image, it is inverted.

Homonymous Image. An image which is projected to the same side of the visual field as the eye which perceives it.

Stereoscopic Image. A single image formed by the fusion of the two retinal images, differing slightly from each other, so as to give the sensation of depth. See **Binocular Vision.**

Upright Image. Same as a virtual image.

Virtual Image. An imaginary image formed by the projection of divergent light waves from a concave lens or a convex mirror to their apparent point of origin. Such an image, as viewed by the eye, is an upright one, because the waves have undergone no crossing.

Image Line. A straight line in the image-space (q. v.) in an infinitely extended plane, in any meridian containing the optical axis of a lens-system.

Image Plane. The plane, real or virtual, perpendicular to the axis, in which are situated the constituent points of an image produced by a lens or a mirror system.

Image Point. Any one of the constituent points in the image plane as described above.

Image Space. The space traversed, actually or virtually, by the effective rays directed toward the constituent points of the image. See **Collinear Space Systems.**

Images of Purkinje. The three catoptric images produced by the surface of the cornea and the anterior and posterior surfaces of the crystalline lens, used for the purpose of demonstrating the presence of the crystalline lens, and for showing the bulging of its anterior surface in accommodation. See **Accommodation.**

Imbalance. See **Heterophoria.**

Incident Ray. Term applied to a ray of light before it strikes a reflecting medium or enters a refracting one. It is, of course, a geometrical quantity with which one calculates the geometrical relations of reflection and refraction.

Inclinometer. A patented instrument for measuring the inclination of the visual axes.

Indirect Vision. The vision which results from the falling of focussed rays upon the peripheral portions of the retina. Although much less acute than direct vision, it is of great practical use in daily life. For further particulars see **Perimetry.**

Index of Refraction. The formula expressing the relative density to light, and therefore the relative refracting power, of a substance as compared with air.

Distinction must be made between the actual quality which the index represents, and the index itself. The actual difference

of refractive density between the air and the substance in question is a function of the opposition which they offer to the speed of the light waves. But the index by which this difference is expressed is a geometric formula, based upon the angles which the incident and the refracted ray make, respectively, with the perpendicular of the refracting surface. The index is as follows:

$$\frac{\text{sine of angle of refracted ray}}{\text{sine of angle of incident ray}}$$

Since the refracted ray makes a less angle with the perpendicular than the incident ray when passing from a rare to a denser medium, the index in that case is a positive quantity. When passing from denser to rarer, the index is a negative, or minus quantity.

Infinity. Actually, of course, there is no such point in practical optics. Light waves coming from such a point would have no curvature, but be neutral waves. However, when waves have traveled 6 meters, or 20 feet, the degree of curvature they possess is so slight, and the segment of the wave that falls upon the eye is so small, that it is regarded as a neutral wave, and 6 meters or 20 feet is regarded as infinity.

Infraduction. Turning of the eye downward.

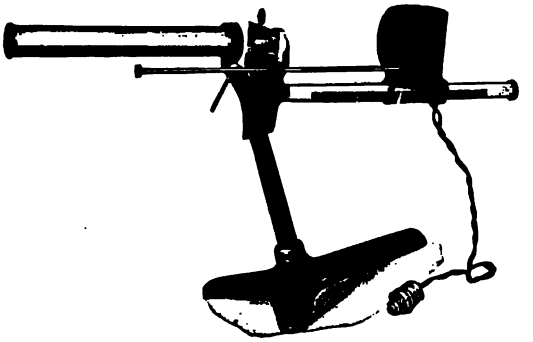
Infraorbital. Beneath the orbit.

Infrared. The invisible heat rays beyond the red end of the spectrum.

Instruments—Oculo Refractive. These instruments are primarily designed to facilitate the work of the operator in ocular and refractive diagnosis. Hundreds are manufactured and the author believes that every one of them has some intrinsic value. Every manufacturer of instruments is prepared to furnish descriptive literature pertaining to his products, going into details so as to enable the operator to obtain the best results, and it would be advisable to communicate with the manufacturers whose names appear in connection with each instrument mentioned.

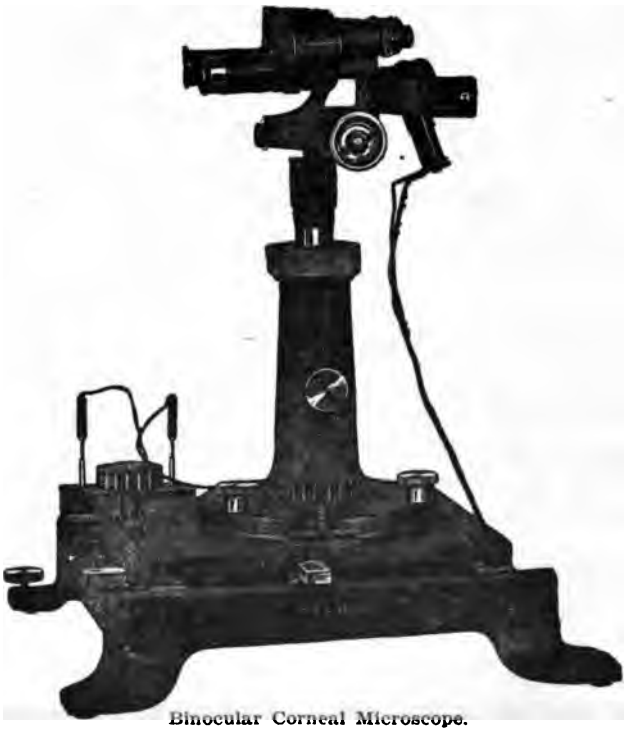
AXOMETER (Lloyd's).

This instrument is designed to determine instantly the axis of a lens. The focus is determined at the same time and with



Lloyd's Axometer.

no extra manipulation. It is also good to examine complete work and broken lenses. Made by the Globe Optical Company, Boston, Mass.



Binocular Corneal Microscope.

BINOCULAR CORNEAL MICROSCOPE.

This corneal microscope gives the proper stereoscopic effect necessary for the examination of the cornea. Owing to its penetrating power, deeper layers of the corneal structure are defined simultaneously with the surface, enabling the operator to follow defective or injured parts of the cornea to a considerable depth. Supplied mounted on a round base or tripod, or with the base of the instrument taking the form of a compound slide arrangement. Furnished with a Gullstrand Illuminating Attachment. Made by the Bausch & Lomb Optical Co., Rochester, N. Y.

BINOCULAR MAGNIFIER.

Used by surgeons, eye, ear, nose and throat specialists, dentists, watchmakers, botanists, geologists and others who must examine small objects with comparatively low magnification. Due to an arrangement of two rhombohedric prisms, it gives not only binocular vision, but a practically natural perspective. The Binocular Magnifier is furnished in magnifications ranging from 0.75 X to 3 X with either fibre or elastic headband, both adjustable. Made by the Bausch & Lomb Optical Co., Rochester, N. Y.

Binocular Magnifier.

CORNEAL MICROSCOPE.

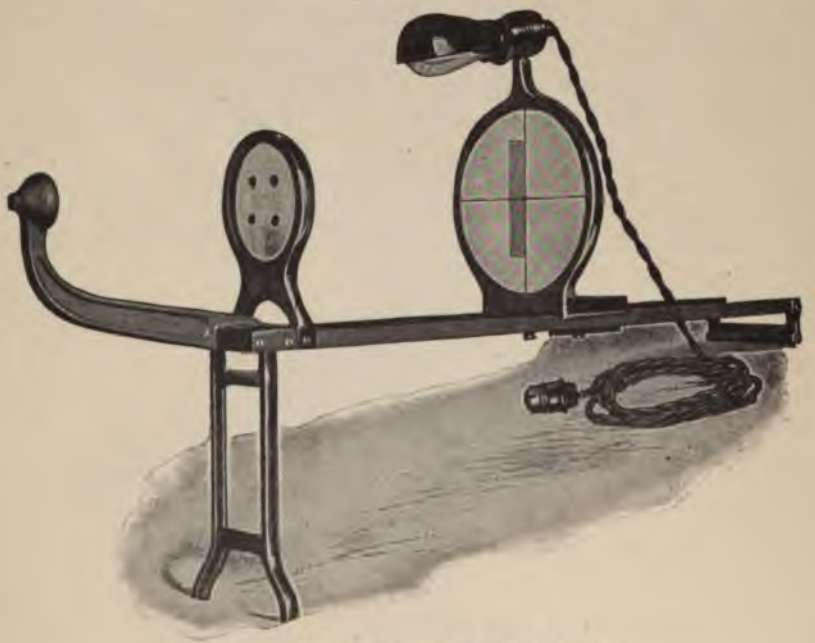
Designed by Dr. Harry Gradle for diagnosing various corneal conditions, such as ulcers, etc., simplified; but any changes in the iris or reaction of the pupil are immediately manifest. The instrument is an attachment for any of the Hardy ophthalmometers. Made by F. A. Hardy & Co., Chicago.

EXOPHTHALMOMETER.

With this little instrument an individual examiner is able to measure exophthalmia accurately and rapidly. The Exophthalmometer is simple in construction and easy to use; it is so made that the outer margins of the orbital cavities of the patient's eyes serve as the base and support of the instrument. Made by the Bausch & Lomb Optical Company, Rochester, N. Y.

GEM AXIS MARKER AND PRISM MEASURE.

An instrument for centering and marking lenses of all kinds. Making it possible to measure prisms and determine the



Gem Axis Marker and Prism Measure.

amount of decentering for a given prism strength. Made entirely of metal with a sliding target through which the light is secured, making it possible to change the distance between the target and lenses for very weak or very strong power. Made by the Globe Optical Co., Boston, Mass.

INTERPUPILLARY GAUGE.

This is an instrument for measuring the distance between the pupils when vision is directed upon distant or near objects. It is very simple to operate, as it does not involve any setting of scale. It measures the distance of either pupil from the center of the bridge of the nose, thereby taking into account the almost universally existing asymmetry of the eyes with respect to that point. Made by the Bausch & Lomb Optical Co., Rochester, N. Y.

Interpupillary Gauge.

KERATOMETER.

The Keratometer enables the operator to measure the diameter of the cornea quickly and accurately. It is also adapted for measuring the distance between the apex of the cornea and the vertex of the spectacle lens. Made by the Bausch & Lomb Optical Co., Rochster, N. Y.

KERATOMETER (Sutcliffe).

A 3 Mire Ophthalmometer which automatically gives a reading on scales after the focus and axis are determined.

LENS MARKING INSTRUMENT (Stoco).

Designed to check the finished work—detecting and indicating the amount of any error in the finished lenses. It also mechanically lays out the work for cutters and edgers. A handy instrument for refractionists. Made by the Standard Optical Co., Geneva, N. Y.

Lens Marking, Centering and Testing Instrument (Stoco).

OPHTHALMOMETER, C. I.

For detecting the presence of corneal astigmatism, measuring it and locating the principal meridians. The principal features of the latest one-position model are the fixed mires, rotat-

C. I. Ophthalmometer.

ing eyepiece and double glass prisms. The advantage claimed by the manufacturers lies principally in the movable eyepiece which eliminates the necessity of revolving the mires to measure the curvature in the second principal meridian. Made by F. A. Hardy & Co., Chicago.

OPHTHALMOMETER (Meyrowitz).

Designed along the Javal-Schiotz idea and including a Wollaston bi-refringent quartz prism and achromatic objec-

Meyrowitz Ophthalmometer.

tives. The latest of the firm's ophthalmometers is known as the Souter, which it is claimed can be used for measuring not only the astigmatism of the cornea but also the anterior and posterior surfaces of the lens. Made by E. B. Meyrowitz, New York.

OPHTHALMOMETER (Universal).

For the purpose of measuring the curvature of the cornea to ascertain whether corneal astigmatism exists and if present,

Universal Ophthalmometer.

to measure the degree of error and to locate the principal meridians. The distinguishing features of this type of ophthalmometer are movable mires, an eyepiece adjustable for the operator's spherical error, and quartz bi-refringent prisms for which the manufacturers claim decided advantages. Made by the General Optical Co., Mt. Vernon, N. Y.

OPHTHALMOSCOPE.

For examining the retina, lens and media. Operates by reflecting light into the eye. The source of the light in some types is located back of the patient, but in more modern and popular models the light is contained within the instrument and is electrically operated. The distinctive types are the Loring, Hare and Morton, between which the difference lies in the shape of the instrument proper and the arrangement of the lenses. There are two general types of mirrors, i. e., those having circular or oval peep-holes and those having U-shaped peep-holes, the latter being known as the Marple type. Manufacturers of ophthalmoscopes in the United States are De Zeng Standard Co., Camden, N. J.; General Optical Co., Mt. Vernon, N. Y., and several others.

OPHTHALMOSCOPE and RETINOSCOPE (Geneva).

The ophthalmoscope and retinoscope is constructed to ascertain the refractive and pathological condition of the eye. With the ophthalmoscope the refractionist is enabled to obtain a highly magnified and clear view of the retina in true colors

Geneva Ophthalmoscope and Retinoscope.

and proportions. It gives a broad field view. The illumination extends over the entire retina and it is not necessary to release the accommodation of the operator or the patient. The special construction of the retinoscope is the construction of the mirror, and with the concealed, concentrated light it gives a clear

shadow movement. The light is close to the mirror, so a strong light is not needed. The instrument presents a convenient working distance; sufficiently great to separate operator from patient and yet close enough to permit the operator to reach the patient's face when necessary. No dark room is necessary for the operation of this instrument. Made by the Geneva Optical Co., Chicago.

OPHTHALMOSCOPE GULLSTRAND.

The large Gullstrand Ophthalmoscope permits an accurate examination and observation of the fundus of the eye, furnishing magnifications of from 5 to 40 times for monocular observation, and 20 times for binocular observation. The stereoscopic effect obtainable with the binocular arrangement is excellent, while the field of view is brightly illuminated by an ingeniously constructed illuminating device supplied with the ophthalmoscope.

The device illustrates "a" as the light source, "b" an aplanatic aspheric lens, "c" the slit of the illuminating system, "d" a diaphragm for confining the field, "e" a second aplanatic aspheric lens, "f" a non-silvered glass wedge, "g" the ophthalmoscope lens and "h" a diaphragm situated in front of the objective and forms the entrance pupil of the observation system.

A specially designed drawing apparatus, by means of which the fundus of the eye under examination can be drawn in detail, can be attached to the instrument, while a special ocular is furnished for demonstration purposes.

Owing to the ingenious construction the manipulation of the apparatus is the simplest possible, and the dimensions of the instrument enable the operator to keep at a convenient distance from the patient, so that no inconvenience whatever is felt during the examination. The chin rest with head support enables the patient to rest comfortably and to keep reasonably steady during the examination, thus greatly facilitating continuous observation.

PHORO-OPTOMETER.

An instrument for subjectively measuring the refraction and muscular condition of the eyes. The complete instrument consists of a battery of trial case lenses, a graduated pupillary adjustment, a brow rest, Risley 30 diopter double rotary prisms, Maddox multiple rods, a Stevens phorometer attach-

ment, a spirit level and an adjustable near point test. The double rotary prism unit is composed of two 15 D. prisms mounted back to back. They rotate in opposite directions and

No. 560 De Zeng Phoro-Optometer.

any prism equivalent from 0 to 30 D. may be obtained. By turning the entire unit, the prism base may be located in any meridian of the circle. The instrument can be had with a floor stand, wall bracket or chair and table attachment. Made by De Zeng Standard Co., Camden, N. J.

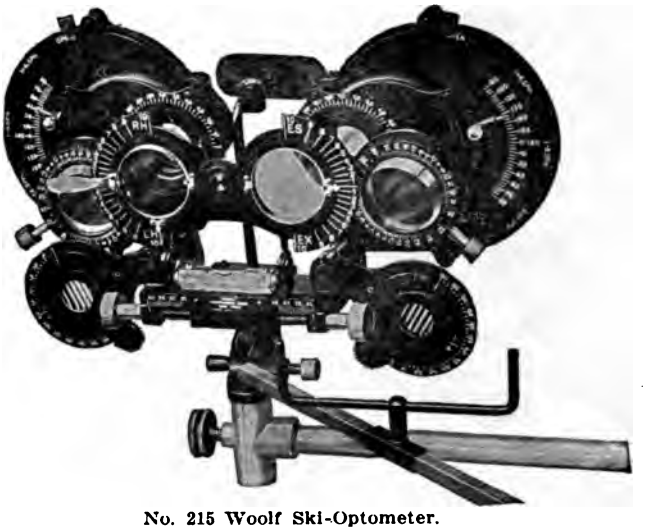
PHORO-OPTOR.

A new instrument designed by the General Optical Company, Mt. Vernon, N. Y., for ascertaining the refraction and the muscular conditions of the eye. Consists of a closed in battery of spheres and cylinders and rotary prisms, Maddox Rods, etc. Supplied with various forms of fixtures.

SKI-OPTOMETER.

An instrument for estimating errors of refraction and muscular balance. It consists of a complete battery of lenses for each eye set in adjustable trial frame with individual pupillary gauge, combined with a double Risley rotary prism for each eye—a red Maddox rod for the left eye and a white Maddox rod for the right eye. There is also a Stevens phorometer at-

tachment. The instrument comes with floor stand, wall



No. 215 Woolf Ski-Optometer.

bracket, chair attachment and table clamp. Manufactured by the Woolf Instrument Corp., New York City.

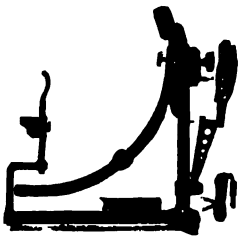
STEVENS PHOROMETER.

This instrument was invented by Dr. Stevens of New York, N. Y. It is composed of Maddox rod over left eye and prisms so arranged that accurate measurement of the vertical and lateral muscles can be made by having the patient look at a spot light 20 feet distant. The principle is binocular. Most of the optometers are equipped with this instrument. It is manufactured by the De Zeng Standard Co., Camden, N. J., and the Woolf Instrument Corporation, New York City.

PERIMETERS.

For measuring the field of vision. Valuable in locating many pathological conditions not detected readily by other means. The new combined electric and daylight perimeter is of the improved McHardy self-registering type and contains Dr. Black's translucent spectral colors in addition to the regular daylight test. Known as No. 475 McHardy Perimeter. No. 460 of the same manufacture is an instrument that combines the valuable points of the Landolt and Priestly Smith perimeters, having the broad metal arc, the revolving chart

No. 460 De Zeng Perimeter.



No. 475 De Zeng Perimeter.

holder, and the sight hole through the center of rotation. It has a double adjustable chin rest and a clip for determining the fixation point. The chart moves with the rotation of the arc and is located just back of a stationary scale, which is graduated in red and white to correspond with the calibrations on the arc. No. 460 and No. 475 are made by the De Zeng Standard Co., Camden, N. J.

Other perimeters on the market are De LaPersonne's, Universal Registering, Forster's, Skeel's Self-Registering, Hare's Automatic, Dana's Pocket Perimeter, Spiller's Hand Perimeter. See also **Campimeter.**

Among the manufacturers of perimeters is the General Optical Co., Mt. Vernon, N. Y.

PLACIDOSCOPE.

Instrument for making an examination of the cornea, including both central and peripheral. Consists of a black disc with

Placidoscope.

white concentric circles, with short focus lens in center. Primarily constructed to detect corneal astigmatism. Made by F. A. Hardy & Co., Chicago.

PRENTICE PHORIA INDICATOR.

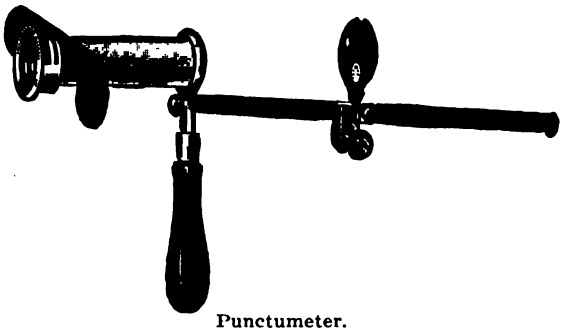
An instrument which is very useful for indicating and measuring the amount of phorias existing in a patient's eye; intended especially for determining hyperphoria, etc., to be corrected by prisms. Designed after suggestions by Charles F.

Prentice Phoria Indicator.

Prentice. Made in the form of a cross, with an electric lamp, which illuminates the eight vertically and eight horizontally arranged green glass discs, placed directly behind a small red glass disc in the center. Made by the Bausch & Lomb Optical Co., Rochester, N. Y.

PUNCTUMETER.

An instrument produced for measuring accommodiation quickly and accurately. It consists of a tube ten centimeters long, into one end of which is inserted a plus lens. Two cells for holding trial lenses are attached to the other end of the tube, one of them being graduated, enabling the operator to place the axis of cylindrical lenses in the proper meridians. A bar upon which is mounted a sliding target operated by a rack and pinion is attached to the end of the tube carrying the lens. This bar also carries a supplementary slide which can be fixed



Punctumeter.

at any point on the bar by a set screw. Made by F. A. Hardy & Co., Chicago.

SPECTRUM PROJECTOR.

This instrument, which is very easy to use, gives a convenient and sensitive means of studying the absorbing effect of various substances on the visible and on the ultra violet regions of the spectrum. It is adapted for absorption determination of ophthalmic lenses. Furnished in two styles; mounted on wooden base or with supplementary base plate and metal screens for testing color. Made by the Bausch & Lomb Optical Co., Rochester, N. Y.

STEREO CAMPIMETER.

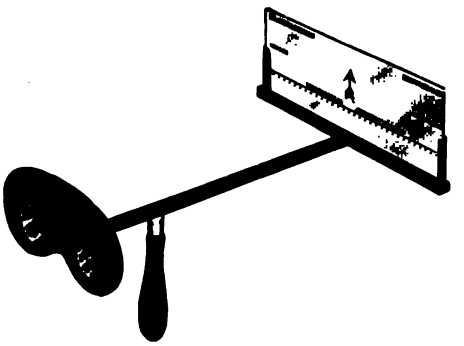
This instrument permits binocular fixation in perimetry and campimetry examinations. The field of the same extends 10

Stereo Campimeter.

degrees nasally, 40 degrees temporally, 30 degrees above and 30 degrees below the center of fixation. The equipment consists of a metal stand with adjustable stereo lens attachment, Lloyd Campimeter Slate mounted on small metal support, 100 Lloyd Campimeter Record Charts, set of test objects and Wells Chart. Made by the Bausch & Lomb Co., Rochester, N. Y.

STEVENSON'S MUSCLE TEST.

Devised by Dr. Mark D. Stevenson to determine the close relationship between accommodation and convergence. This



Stevenson's Muscle Test.

test helps to decide the best reading distance for the patient. Also frequently important in prescribing prisms or the centering of lenses. Made by F. A. Hardy & Co., Chicago.

TEST CABINET.

An arrangement for holding and illuminating test charts used in subjective testing. Hundreds of cabinets, electrical and otherwise, and made in various designs and colors to match the furniture of the office, some being on stands, some on brackets, others for mounting on walls. Made by the Bausch & Lomb Optical Co., Rochester, N. Y.; M. E. Green Mfg. Co., St. Louis, Mo.; Globe Optical Co., Boston, Mass.; F. A. Hardy & Co., Chicago; Merry Optical Co., Kansas City, Mo.; Gould Optical Equipment Co., New York, and others.

TEST LENSES (Ophthalmic), VERTEX.

These are numbered in vertex refraction. Each lens in the set being of the same thickness, a given cylinder always gives the same cylindrical effect, regardless of the sphere with which it may be combined. The lenses are 15 mm. in diameter, mounted in 32 mm. discs, and give approximately axial refrac-

Bausch & Lomb Ophthalmic Test Lenses.

tion. Can be had in portable case; also in sanitary glass and metal enameled cabinet having a small formalin vaporizer for sterilization purposes as well as space for the test frame and other accessories; it may also be had in white enameled cabinet (wood) with opal glass plates at each end affording space for auxiliary instruments, drawers below for test frame, etc., also four more drawers. Made by the Bausch & Lomb Optical Co., Rochester, N. Y.

TONOMETER.

Designed for measuring the tension of the eyeball, especially valuable in cases of glaucoma. There are several types of tonometers.

TRIAL CASE.

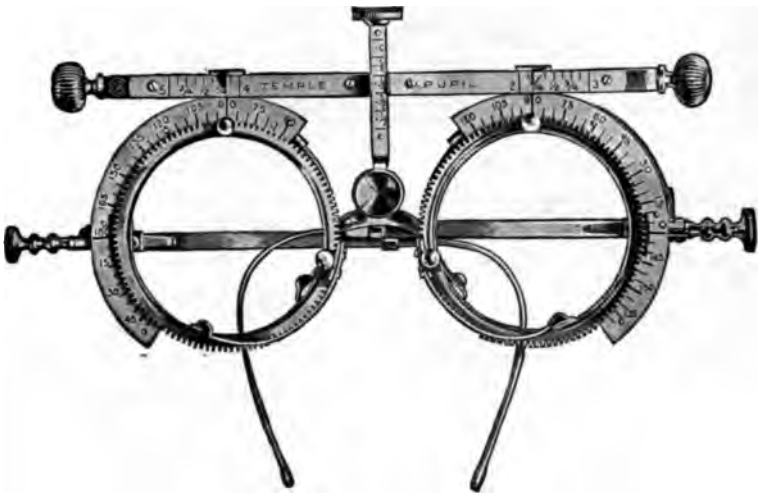
Contains spherical and cylindrical lenses and other accessories used in subjective refraction. Made by the American

American Optical Co. Trial Case.

Optical Co., Southbridge, Mass., and Bausch & Lomb Optical Co., Rochester, N. Y.

TRIAL FRAME.

Made with three cells, two of which are revolved by thumb screws. The bridge is self-adjusting for angle of the nose.



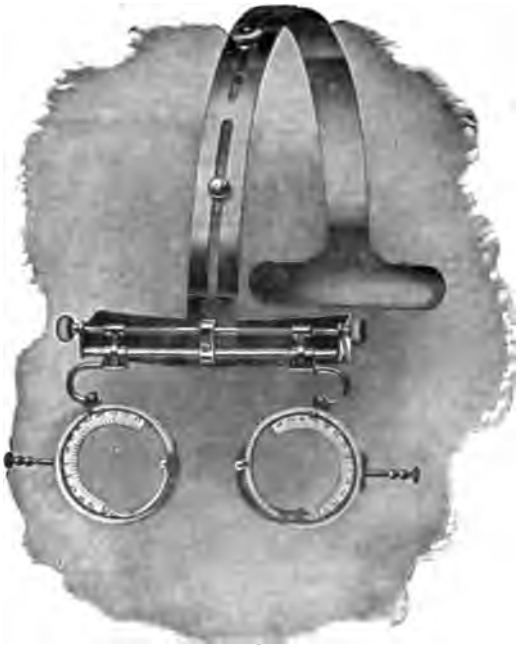
American Optical Co. Trial Frame.

Frame is adjustable for pupillary distance, height of bridge and length of temple. Supplied either with comfort or wire temples. There are quite a variety of trial frames made by the same concern, including some for presbyopic correction only,

as also square cell frames for prisms, and many other kinds. Made by The American Optical Co., Southbridge, Mass.

TRIAL FRAME (California).

It consists of a specially constructed adjustable and folding head-band—deep set eye lenses can be set in close—with protruding eyes or long eyelashes lenses can be set accordingly.

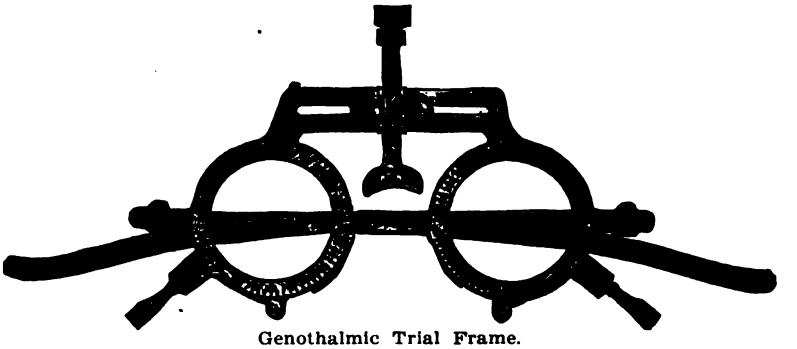


California Trial Frame.

The reading angle is obtained by tilting lens cells forward The axis scale is placed inside of lens cell. The frame can be taken apart and folded in a compact form. Made by the American Optical Co., Southbridge, Mass.

TRIAL FRAME (Genothalmic).

This frame possesses straight spring temples, which have just enough tension to hug the face comfortably and securely. The straight temples permit of easy putting on and off the frame. A tilting device allows the entire frame to be tilted for-



Genothalmic Trial Frame.

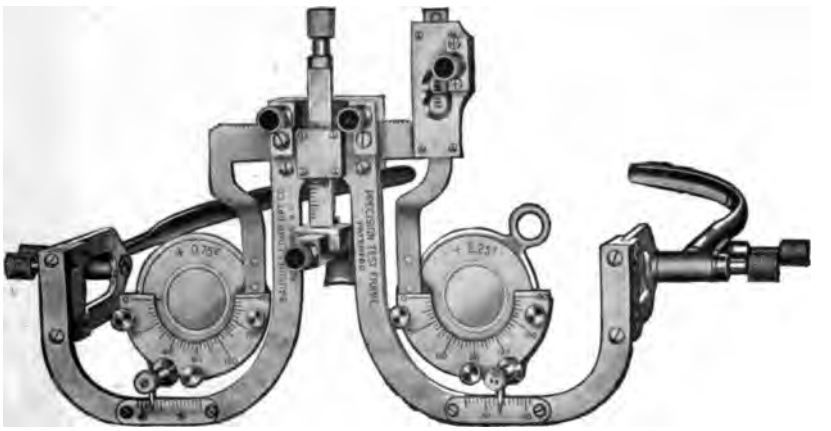
ward for the reading test. The temples remain in their original position. Made by the General Optical Co., Mt. Vernon, N. Y.

TRIAL FRAME (Genothalmic Clinical).

It consists essentially of two steel plates joined at the center by extension pieces which are toothed inside to form a double rack. An adjustment for interpupillary distance is accomplished by placing a pinion between the racks. The bridge is brought to the required height by pushing the pinion up and down in the rack. The dials are engraved on a stationary steel rack which holds the lenses. The temples are the same as those in the Genothalmic Frame. Made by the General Optical Co., Mt. Vernon, N. Y.

TRIAL FRAME, PRECISION (Precision Test Frame).

A test frame scientifically constructed throughout, having



Precision Test Frame.

all the adjustments necessary to enable the operator to make accurately and quickly the measurements required. Its manipulation is simple. It is not necessary to write details of an examination during the examination, as they can be secured from the scales on the frame. Made by the Bausch & Lomb Optical Co., Rochester, N. Y.

TRIAL FRAME (Stoco).

The frame is constructed so that each eye and each temple move independently, enabling the operator to detect and record any deviation from symmetry in features. It has a graduated bar at the top carrying two sets of brackets. The temples are operated independently of one another by means of right and left screws. The nose piece has a swinging bridge to fit any shape of nose. The temples slide and change in length by means of a small set screw. Manufactured in two sizes of eye—1¼ in. and 1½ in. Can be had with two or three cells. There are many other kinds of trial frames manufactured by the same firm. Made by the Standard Optical Co., Geneva, N. Y.

VISUAL ACUITY TEST WITH IVES SCREEN.

This apparatus consists of parallel lines or of squares, the distance between which in the first case or size in the second can be varied continuously from invisibility to easy visibility. It also lends itself admirably to the determination of the axis of astigmatism. Made by the Bausch & Lomb Optical Co., Rochester, N. Y.

Insufficiency. A term applied to the condition of the muscle which, in strabismus or in imbalance, appears to be the weaker. Thus, in internal strabismus, we speak of insufficiency of the external muscles.

Intercilium. The space between the eyebrows.

Internus. Applied, for short, to the internal rectus muscle.

Interorbital. Between the orbits.

Interval, Sturm's. The interval between the anterior and posterior foci in astigmatism. Sturm found that distant objects are seen in the posterior interval and near objects with the anterior.

Intraocular. Within the eyeball.

Intraorbital. Situated within the orbit.

Intumescent Cataract. The rapid development of a senile cataract, sometimes due to acute glaucoma.

Iridalgia. Pain in connection with the iris.

Iridallochrosis. Change of color in the iris.

Iridauxesis. The same as Iridoncus.

Iridectomy. The operation of cutting away a small piece of the iris. It is done (a) for optical purposes, to improve vision, (b) to relieve intraocular tension, and (c) as a preliminary to cataract extraction.

Iridenclesis. An operation for displacing the pupil.

Irideremia. Defective iris.

Iridesis. Tying off a portion of the iris to form an artificial pupil.

Iridescent Vision. An appearance of colors around the borders of the image.

Iridic. Pertaining to the iris.

Iridoavulsion. Tearing of the iris from its periphery.

Iridocele. Hernia of the iris.

Irido-Chorioiditis. Joint inflammation of the iris and choroid.

Iridocinesis. Expansion and contraction of the iris.

Irido-Cyclitis. Joint inflammation of the iris and the ciliary body.

Iridodesis. A form of iridoclesis.

Iridodialysis. Separation of the iris from the ciliary body.

Iridodonesis. Trembling of the iris.

Iridoncus. Swelling or tumor of the iris.

Iridoperiphacitis. Inflammation of the iris and lens capsule.

Iridoplania. Trembling of the iris.

Iridoplegia. Paralysis of the iris. See **Reflex.**

Iridorrhexis. Rupture of the iris.

Iridosclerotomy. Puncture of the sclera and iris.

Iridotomy. The cutting of a small slit in the iris. It is done for the same purposes as iridectomy.

Iris. The vascular curtain which hangs suspended in the aqueous humor, in front of the crystalline lens. It is really a part of the second tunic of the eye, of which the chorioid and the ciliary body are also parts. It springs, in fact, from the anterior surface of the ciliary body, its free margin extending into the aqueous chamber. It steadies itself against the crystalline lens at its back, so that it forms a shallow cone, corresponding to the anterior convexity of the lens, with its apex looking forward. In the absence of the lens, (as after cataract operation), the iris may be seen to tremble, lacking its support. Similar trembling, in very slight degree, may be seen when the pupil is greatly contracted, because the margin of the iris floats away from the lens and the iris itself is much thinned.

The vessels of the iris, derived from the long posterior and the anterior ciliary arteries, run from the ciliary to the pupillary margin, and near the latter margin they interlace to form the minor circle of the iris, dividing the iris into two zones, the ciliary and the pupillary zone. On the pupillary margin there is a black fringe, which becomes very visible in a cataractous eye, because of its contrast with the yellowish-white lens. Around the minor arterial circle and around the ciliary root of the iris are indentations and crypts, devoid of membrane, which are really apertures leading into the interior of the iris substance. These openings mechanically favor the changes of size which the iris undergoes during expansion and contraction.

The stroma of the iris consists principally of radiating vessels running from the ciliary to the pupillary margin. Near the pupillary margin is the sphincter muscle of the iris, which contracts the pupil, embedded in the stroma. On the anterior surface of the iris are two membranes, viz., the anterior limit-

ing membrane and a continuation of Descemet's membrane. On the posterior surface there are also two, viz., the posterior limiting membrane, consisting chiefly of the radiating muscles which dilate the pupil, and the retinal pigment layer. This latter layer represents the continuation of the retina, and may be regarded as the retinal part of the iris, as distinguished from the uveal part.

COLORING.

The iris contains two pigments: one in the stroma, which is brown, and one in the retinal pigment layer, which, seen through the iris, appears blue or gray. The color of the eye is therefore either brown or blue, according to the domination of one or other of these two pigments. If the stroma pigment is plentiful the color is brown; if scanty, it is blue. If the stroma pigment is scanty, but the iris itself thick, the color is gray. Children are born always with blue eyes, but during the first few years of life the color changes, owing to the thickening of the iris stroma. Occasionally this change may develop in one eye after birth and not in the other, in which case one eye is blue and the other brown. Not infrequently, while the general stroma pigmentation is poor, there may be isolated spots in which the pigment is thick which gives a flecked or mottled appearance to the eye.

MUSCULATURE.

The iris is furnished with two sets of muscles: (1) the concentric muscles, whose contraction diminishes the size of the pupil, and whose nerve supply comes from the third nerve, through the ciliary ganglion, and (2) the radiating muscles, whose contraction dilates the pupil, and whose nerve supply comes from the cervical sympathetics. These two sets of muscles oppose each other. Light falling on the retina causes the concentrics to contract; sensory impulses from anywhere in the body cause the radiating muscles to contract. Whichever of these two stimuli is strongest at the moment determines the size of the pupil.

Optically, the function of the iris is to vary the size of the pupil, so as to serve as a cut-off, to protect the [illegible] excess of light, and to insure properly graded [illegible] for a clear image.

Iris Shadow. The shadow which the iris casts on a cataract. As long as this shadow is visible the cataract is not yet ripe. When it is ripe, the iris no longer casts a shadow on it.

Iritic. Pertaining to the iris.

Iritic Angle. The angle formed by the junction of the iris and the cornea.

Iritis. Inflammation of the iris, usually due to some internal disease, such as rheumatism, syphilis, etc. The symptoms are not difficult to recognize: Pain, worse at night, because then the pupil is dilated and the iris bunched upon itself; dimness of vision due to the outpouring of muco-serum into the aqueous humor; cloudinness of the media, from the same cause; ragged appearance of the iris itself, which also loses its beautiful lustre Occasionally the iris becomes glued down to the lens by the exudates. The pain of iritis is usually felt in the brow.

It is a serious condition, and should be referred at once to an oculist.

Irregular Astigmatism. See **Astigmatism.**

Ischemia. Lack of blood in a part.

Ischemia Retinae. Pallor of the retina due to bloodlessness.

Isocoria. Equality in the size of the pupils.

Isometropia. Equality in kind and degree in the refraction of the two eyes.

Isopter. A curve in the visual field drawn through points of equal acuity of vision.

Isosceles. Term applied to a triangle which has two of its sides equal.

Jaeger's Test Type. A type for testing near vision. See **Type.**

Joffroy's Symptom. A symptom observed in exophthalmic goitre. When the eyes are suddenly turned upward, there is no facial contraction. It is the obverse of Graefe's Sign.

Kataphoria. See **Cataphoria.**

Kayser's Disease. An affection marked by a greenish discoloration of the cornea—associated with different organic conditions.

Keratalgia. Pain in the cornea.

Keratectasia. Protrusion of the cornea.

Keratitis. Inflammation of the cornea. When the disease is acute there is dull aching pain in the eye, injection of the circum-corneal vessels, watering of the eye, and steaminess of the cornea. When chronic, the cornea is dull and partially opaque, lessened in sensibility, and painless.

The injection of keratitis is a ciliary injection, and is to be distinguished from that of conjunctivitis by being pink in color, located on either side of the cornea, and none of the separate vessels being distinguishable.

Interstitial keratitis, in which the cornea becomes white and opaque, is usually due to inherited syphilis.

Keratocele. Protrusion of Descemet's membrane through the outer layers of the cornea.

Keratoconus. A condition of the cornea in which it is bulged forward in the form of a cone. Refraction is of course interfered with.

Keratoglobus. A globular protrusion of the cornea.

Keratohelcosis. Ulceration of the cornea.

Kerato-Iritis. Joint inflammation of cornea and iris.

Keratomalacia. Softening of the cornea.

Keratome. A lance-shaped knife for opening the cornea.

Keratometer. Same as an ophthalmometer q. v.

Keratomycosis. Fungus growths on the cornea.

Keratonyxis. Rupture of the cornea.

Keratoplasty. Plastic surgery of the cornea.

Keratoscleritis. Joint inflammation of the cor[illegible] sclera.

Keratoscope. An instrument for examining the cornea.

Keratoscopy. Examination of the cornea.

Kerectomy. Removal of part of the cornea.

Kilometer. One thousand meters.

Kopiopia. See **Copiopa.**

Korectomia. Making of an artificial pupil by removing a part of the iris.

Korectopia. Displacement of the pupil.

Koroscopy. Same as Retinoscopy.

Kryptok. A trade name given to a patented bifocal lens, made by fusing together two pieces of glass, of differing density, for the distance and the near correction, respectively. See **Lens.**

L. and L. E. Abbreviation for left eye.

Lachrymal Apparatus. The apparatus for secreting and disposing of the tears. The tears are secreted by the lacrymal gland, which consists of two parts, the superior, lying in the upper outer angle of the orbit, and the inferior (accessory) lying under the mucous membrane of the fornix. Both empty into the conjunctival sac by means of ducts.

The tears drain through the lacrymal sac, which opens from the lower eyelid, near the inner fornix, with the puncta lacrymalia; thence through the lacrymal duct into the nasal cavity, just behind the lower turbinate bone.

Lachrymation. Overflow of tears from the eyes.

Lachrymotony. Cutting of the lachrymal duct to cure a stricture.

Lacrimal. Same as **Lachrymal.**

Lacrymal. The same as **Lachrymal.**

Lacuna Orbitae. The roof of the orbit.

Lacus Lachrymalis. The area of the eye near the inner canthus where the tears collect.

Laevophoria. A conjugate muscular imbalance, in which both eyes tend to turn toward the left.

Lagophthalmia. A condition in which it is impossible to close the eyes.

Lakus. The small circular opening at the inner fornix of the eyelids.

Lambert's Law. The amount of light which passes through a colored filter or glass plate diminishes in geometrical progression as the thickness increases in arithmetical progression.

Lamina Cribrosa. Literally, a perforated plate. Fibrous bands of the chorioid which bridge over the foramen sclerae, pierced by the funiculi of the optic nerve. It is the weakest spot in the tunics of the eyeball, and therefore the first to give way under intra-ocular pressure, as in glaucoma.

Lamina Fusca. The outer layer of the cornea.

Lamps. See **Illumination.**

Landolt's Bodies. Small bodies found between the rods and cones of the retina.

Lantern Tests. Tests for color-blindness, q. v.

Lapsus. Dropping of the upper lid. See **Ptosis.**

Lashes. The hairs that grow upon the margins of the eyelids.

Latent. That which is not made manifest, but exists only potentially. In optics it is especially applied to hyperopia which has taken the form of a muscle spasm, and cannot be brought out by tests (See **Hyperopia**), and imbalance of the extrinsic muscles which has not yet become actual squint. (See **Strabismus**).

Lateroduction. See **Muscles.**

Law. The expression of a sequence of natural events which occur under a given set of conditions.

Angstrom's Law. The wave-lengths of the light absorbed by a substance are the same as those given off by it when luminous.

Brewster's Law. For any substance the polarizing angle is equal to the angle of incidence at which the portion of light that is reflected is at right angles to the portion that is refracted.

Descarte's Law. The sine of the angle of incidence bears a constant ratio to the sine of the angle of refraction for two given media.

Donder's Law. See **Donders.**

Giraud-Telon's Law. Binocular retinal images are formed at the intersection of the primary and secondary axes of projection.

Gullstrand's Law. If, when a patient is made to turn his head while fixing a distant object, the corneal reflex from either eye moves in the direction in which the head is turning, it moves toward the weaker muscle.

Kirchoff's Law. When a pencil of light is passed through a transparent body, the latter absorbs only those luminous rays which it is capable of emitting when heated to incandescence. (This, as will be seen, is the equivalent of Angstrom's law).

Malus' Law. An orthotomic system of rays remains orthotomic, no matter what refractions or reflections the rays may undergo in traversing a series of isotropic media.

Law of Absorption. The proportion of transmitted radiation varies geometrically as the thickness of the absorbing medium varies. See **Absorption.**

Law of Projection. An impression made on any point of the retina is projected outward into the visual field following the line of direction, i. e. a line passing from that retinal point through the nodal point of the eye.

Law of Reflection. See **Reflection.**

Law of Refraction. See **Refraction.**

Law of Sines. The sine of the angle of incidence is equal to the sine of the angle of reflection multiplied by a constant.

Prentice's Law. Any lens is capable of producing as many prism dioptres as the lens possesses dioptres of refraction, provided it is decentered one centimeter.

Talbot's Law. When complete fusion occurs, and the sensation is uniform, the intensity is the same as would occur were the same amount of light spread uniformly over the disc.

Wundt-Lamansky's Law. The line of vision, in moving through a vertical plane parallel to the frontal plane, moves in straight lines in the vertical and horizontal directions, but in curved paths in all other movements.

L. D. Abbreviation for light difference, denoting the different light reaction of the two eyes.

Leber's Disease. Hereditary optic atrophy.

Lema. Dry, hard, yellow incrustation in the inner canthus.

Lens. In general, a lens may be defined as any agent which transmits and refracts light waves, in such a way as to produce an image of the object. It has three principal functions: (1) to produce an image larger than the object, as in microscopes; (2) to produce an image smaller than the object, as in photographic camera: and (3) to produce an image at a desired focal plane, as in ophthalmic lenses.

As the curvature of a light wave is spherical, and as it is the purpose of ophthalmic lenses to bring light waves to a series of focal points similar to those from which they originated, it follows that the curvature of ophthalmic lenses must be similar in nature to that of the waves, i. e. spherical. Frequently, however, it is desired to influence the light wave in only half of its meridianal curve, and for this purpose lenses are employed whose curvature is a segment of a cylinder, which may be regarded, in its optical effect, as the split half of a sphere. Ophthalmic lenses, then, are spherical and cylindrical; commonly known as spheres and cylinders.

In accordance with the laws of refraction, light waves, upon entering glass lenses, whose refractive index is greater than that of air, are refracted toward the normal. Hence, in order to render a light wave more convergent it is necessary that the surface of the lens be convex; to render it less convergent, or more divergent, it must be concave. Ophthalmic lenses, therefore, are convex and concave; commonly termed plus and minus, respectively.

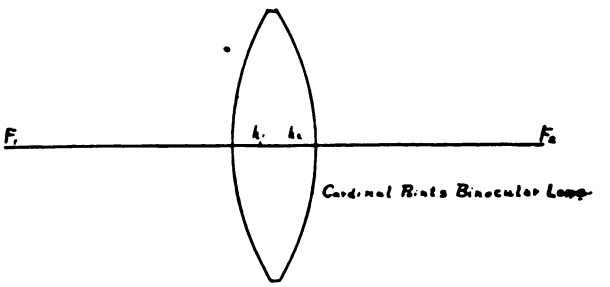
Images of objects are made by lenses in accordance with a theory of optical representation first formulated by Abbe. If

a pencil of rays, i. e. the totality of rays or waves proceeding from a luminous point fall on a lens or lens system, a section of the pencil will be transmitted. The emergent waves will have directions differing from those of the incident waves; the alteration, however, being such that the transmitted waves are convergent in the "image-points" just as the incident waves are convergent in the "object-points." With each incident wave is associated an emergent wave; such pairs are termed "conjugate waves." Similarly, the object-point and the image-point are conjugate points. All object-points lie in the object-space, and all image-points in the image-space.

A lens has four cardinal points, as follows:

(1) An anterior, or first, principal focus
(2) A posterior, or second, principal focus
(3) An anterior principal point
(4) A posterior principal point (See **Points**)

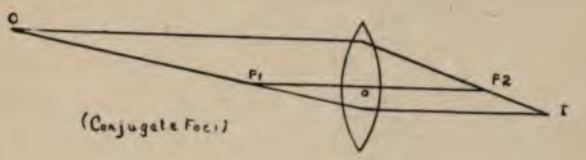
From these four points all object-image relations can be calculated.



To determine the image-point for any given object-point, we first choose a ray from the object-point which runs parallel to the axis, and follow its course through the lens to the point on the further side of the lens where it meets the axis, namely, the posterior principal focus. We then choose another ray from the object-point which passes through the anterior principal focus and follow its course through the lens (which renders it parallel with the axis) to the point where it intersects the first refracted ray, projected through the posterior principal focus to meet it. In other words, the image-point will be found at the intersection of two rays from the object-point, one of which passes through the anterior principal focus

and the other through the posterior focus. This is evident, because any rays passing through these two focal points are conjugate.

The above construction does not apply when the object-point is at infinity. In that case the image-point will be in the perpendicular plane through the posterior principal focus,



The distance between the principal point and the principal focus on either side of the lens is called the focal length of the lens. The relative sizes of object and image are as their respective distances from the anterior and posterior principal points.

In addition to the four cardinal points mentioned, a lens has two nodal points—points within the lens on the principal axis from which object and image appear under the same angle—and an optical centre, such that for any ray which passes through it the incident and emergent rays are parallel.

In ordinarily thin ophthalmic lenses, the principal points, the nodal points, and the optical centre are all so close together that they are regarded as being identical, the lens is considered as having no thickness, and all focal measurements are pivoted on the optical centre. The two refracting surfaces, of which every lens is composed, are regarded as a single refracting surface, equal in dioptric value to the sum of the two, acting in the plane of the optical centre.

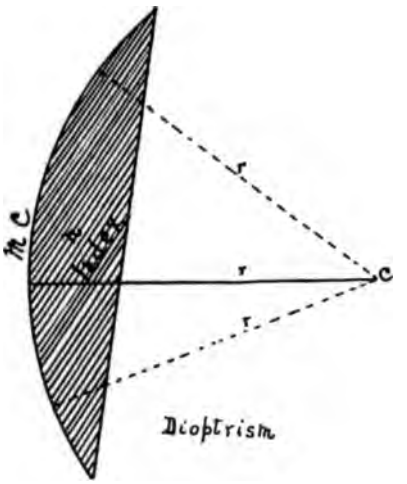
The refracting power of such thin lenses, known as the dioptrism, depends upon two factors: (1) the degree or radius of curvature of the surfaces, and (2) the index of refraction of the substance of which the lens is made. The unit of curvature is the meter curve, i. e. a curve whose radius is 1 meter. The unit of refracting power is the dioptre, i. e. the power to focus a neutral wave in 1 meter distance. The ratio between the meter curve and the dioptre is determined by the index of

refraction. The dioptric power is that percentage of the meter curve denoted by excess index over air (expressed as n-l). The formula for this ratio is:

$$D = mc\ (n\text{-}l)$$

Or, if the curvature is e xpressed in terms of the radius, since this radius is the reciprocal of the curve, the formula will be:

$$D = (n\text{-}l)/r$$



It must not be supposed, however, that the index element operates alike at both surfaces, i. e. that the excess index of the glass multiplied by the meter curve represents the dioptrism at each surface. Considering the lens, surface by surface, it must be remembered that the index-ratio is not the same at both surfaces. When the light enters the first surface, the glass is the refracting medium; the index-gain in thus passing from air to glass is .52; and it is this proportion of the glass-index which operates at the first surface. The dioptrism of the first surface, therefore, is expressed in the following formula:

$$D_1 = \frac{1}{r_1} \times \frac{(n\text{-}1)}{n} = \frac{(n\text{-}1)}{r_1 n}$$

On emergence from the lens at the second surface, the air becomes the refracting medium; the index-loss is .52; and it is this proportion of the air-index that is operative at the second

surface. Furthermore, the metric curve of the second surface is now modified by the meter curve of the light in the lens. In a bi-convex lens both these are minus curves, and the index element, therefore, operates on the net sum of the two curves. Thus, the action at the second surface, is expressed in the formula:

$$D_2 = \left[\frac{1}{r_2} + \frac{(n-1)}{r_1 n}\right] \times \left[\frac{(n-1)}{1}\right]$$

Thus, if we have a bi-convex lens whose front surface has a radius of curvature of 16.6 cm., and its back surface a radius of 25 cm., and whose index of refraction is 1.52 (to simplify the problem we will call it 1.50), then the action at the first surface will be

$$\frac{.50}{16.6 \times 1.50} = 2\ D.$$

and the action at the second surface will be:

$$\frac{1}{.25} + 2 \times \frac{.50}{1.00} = 3\ D.$$

making the combined dioptrism of the two surfaces 5 D., or just .50 of their combined metric curve.

In thick lenses, where the distance between the two surfaces is a modifying factor, this method of calculation will not apply. In such cases the focal values of the two surfaces are separated by a distance (within the lens, on the axis) depending upon the thickness of the lens, its refractive index, and the radii of curvature of the two surfaces, thus making the distance of the posterior principal focus further from the anterior surface than the reciprocal of the combined dioptrism of the surfaces, and the distance from the posterior surface (the vertex) less. The refraction performed at the posterior surface is technically known as vertex refraction, and the subject will be found discussed under that heading.

To determine the vertex refraction of a lens, if D stands for the required power, r_1 for the radius of the first surface, r_2 for the radius of the second surface, d for the thickness of the lens, and n for the index, then,

$$D_r = \frac{1}{\dfrac{r_1 n - d}{(n-1)}} + \frac{(n-1)}{r_2}$$

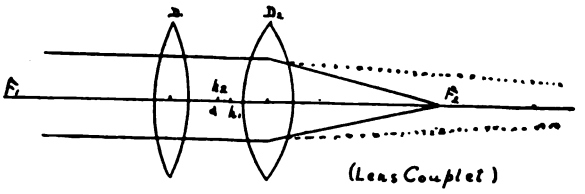
The distance of an object from the optical centre (or, if thickness is to be considered, from the first principal point) of a lens is called the anterior focal distance; that of the image from the optical centre or the posterior principal point, the posterior focal distance. Representing the former by u, the latter by v, and the focal length of the lens by f, then,

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

and this formula furnishes the basis for all calculations connected with conjugate relations.

LENSES IN SERIES.

When two or more lenses are placed one behind the other, on the same principal axis, they are said to be in couplets or series. When two such lenses are in close apposition, their combined power is practically the sum of their individual powers—not exactly, because of the impossibility of exact apposition, but this slight discrepancy may be ignored. When, however, they are separated by an appreciable space, the separation modifies their joint power in a way depending upon the nature of the lenses. Negative power is increased, positive power decreased, by such separation.



There is a unit space between any two lenses which modifies their joint power by just 1 D., and this unit space is the product of their focal lengths. Thus, if we take two plus lenses of 4 D. and 10 D. respectively, the focal lengths of these two lenses are 25 cm. and 10 cm. respectively, and the product of

.25 and .10 is .25. Separation of the lenses in question by .25 cm. will reduce their joint power from 14 D. to 13 D.

To determine the effect of separation we subtract from the sum of the two individual lens powers the product of these powers and the distance of separation as a fraction of a meter. If D stands for the net power sought, D_1 for the power of the first lens, D_2 for the power of the second lens, and d for the distance of separation, then,

$$D = D_1 + D_2 - (D_1 D_2 d)$$

Thus, in the illustration just given, i. e. a plus 4 D. and a plus 10 D. separated by 2.5 cm., we have

$$D = 4 + 10 - (4 \times 10 \times .025) = 13 \text{ D.}$$

Or, if we wish to find the focal length of the two separated powers, we have only to divide the quantities into unity, so that the formula becomes:

$$f = \frac{1}{D_1 + D_2 - (D_1 D_2 d)}$$

Or, if we are working with the radii of the lenses instead of dioptric values, then we have

$$D = \frac{(n-1)}{r_1} + \frac{(n-1)}{r_2} - \frac{(n-1)^2 d}{r_1 r_2}$$

LENSES WITH THICKNESS.

When the thickness of a lens is to be taken into account in calculating its dioptrism, its two surfaces really constitute a couplet of separated lenses in which the distance of separation is traversed by the light in glass. The same method and formulae of calculation, therefore, apply as were applied to separated lenses, except that the distance of separation, i. e. the thickness of the lens along its axis, must be divided by the index of the glass in order to reduce it to an equivalent of thickness in air. That is to say, the quantity represented by thickness being expressed, as the distance of separation was, by the letter d, then $d = t/n$.

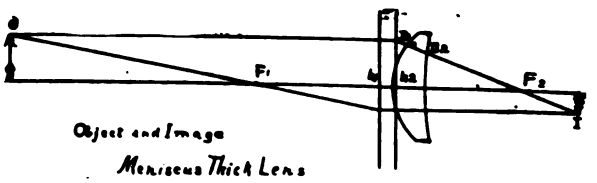
Thus, if we have a meniscus lens, whose front surface (D_1) is a plus 6, its back surface (D_2) a minus 4, its thickness 5 mm., and its index 1.52, then to calculate its net dioptrism the following formula applies:

$$D = D_1 + D_2 - (D_1 D_2 t/n)$$

Substituting the values for the letters, we have

$$\begin{aligned} D &= 6 + -4 - (6 \times -4 \times 5/1.52) \\ &= 2 - (-24 \times .003283) \\ &= 2 - (-.078792) \\ &= 2 + .078792 = 2.078792 \text{ D.} \end{aligned}$$

which is the true net value of the lens.



The optical centre of the lens is calculated as follows:

$$O = \frac{D_1 t}{D_2} \text{ anterior to back surface}$$

$$= \frac{6 \times .005}{2} = .015 \text{ ant. to } D_2$$

The posterior principal point differs from the above in that the divisor is the net value of the lens instead of its nominal value. Hence the formula:

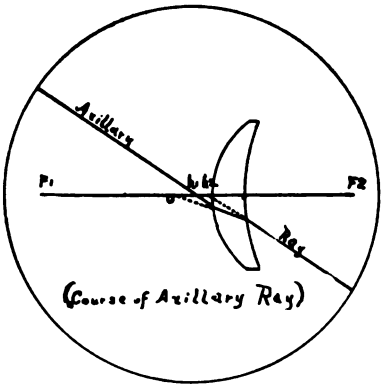
$$h_1 = \frac{D_1 t/n}{D} \text{ forward of } D_2$$

$$= \frac{6 \times .003283}{2.078792} \text{ anterior to } D_2$$

The position of the anterior principal point is similarly calculated, except that —4 takes the place of +6, and the distance is measured from the anterior surface or pole. This locates it as follows:

$$h = \frac{-4 \times .003283}{2.078792} \text{ posterior to } D_1$$

However, since the factor —4 here is a negative factor, the result will be a minus distance, and minus-posterior is anterior; hence both principal points are in this case anterior to the front surface.



Ordinary lenses are made of crown glass, having a refractive index of approximately 1.52. With regard to their two surfaces, they are made in several different forms, as follows:

Bi-convex, in which the action of both surfaces is positive. The refractive effect is then the sum of the two surfaces, both surfaces rendering light waves more convergent.

Bi-concave, in which both surfaces have a negative action. Both surfaces then render light waves less convergent, or more divergent, the net result being the sum of the two actions.

Convexo-concave (meniscus), where the action of the front surface is positive and that of the back surface negative, the positive action dominating, so that the net result is a positive dioptrism equal to the difference between the two surfaces.

Concavo-convex (meniscus), similar to the foregoing, but with the negative surface dominating, so that the net effect is a negative dioptrism equal to the difference between the two.

Plano-convex and plano-concaves are no longer made, except when a prism is to be ground on one side of the lens.

Meniscus lenses are the commonest form of spherical lens; they are also known as periscopic lenses, because they conform to the rotation of the eyeball, permitting the visual axis to cut the two surfaces of the lens in any direction almost pendicularly.

Frequently it is necessary to make a lens which shall have both a spherical and a cylindrical effect, in which case the

sphere is ground on one surface and the cylinder on the other. Such lenses are known as compound lenses.

Compound lenses are made either in bi-convex or bi-concave form, as the case may be, or else in meniscus form, the latter being known as toric lenses, (from the Greek word **toros,** meaning the elliptical base of a column), because the surface on which the cylinder is ground has an elliptical curve. Toric lenses are ground on standard spherical bases, 3D, 6D, and 9D, according to the required dioptrism, the cylindrical surface being then ground so as to give the required compound effect. (Other bases, of different values, are nowadays used by various manufacturers). The toric lens is by far the best form for a compound, because it is periscopic, and reduces to a minimum the prismatic effect which would otherwise be experienced in looking obliquely through the sphere and cylinder.

When it is desired to combine a prism with a lens this may be done either by grinding a prism on one side of the lens, or, better, if there is sufficient dioptric power in the lens, by decentering it sufficiently to obtain the desired prism effect. (See **Decentration**).

When it is desired, in the case of a presbyope, to combine in the same lens correction for distance and correction for near point, this is accomplished by means of a bifocal lens. (See **Bifocal**).

A spherical lens may be said to be a radiating series of prisms, whose bases meet at the optical centre of the lens in the case of a convex lens,—the apices in the case of a concave lens. Hence, if we view an object through a spherical lens any other than through its optical centre there is an apparent displacement of the image in the direction of the apices of these prisms—in convex lenses toward the periphery of the lens, in concave lenses toward the centre. This displacement increases, the nearer to the apex our visual axis pierces the lens. The effect of this is that if we move a lens to and fro between our eye and an object, the image will appear to move —in the same direction that we move a concave lens, in the opposite direction to that in which we move a convex. This is what is called the parallax of the lens; it serves to identify

the nature of the lens, and by finding a lens of opposite kind which, when imposed upon it, stops this parallax movement, we can determine its dioptric strength. (See **Neutralization**). The same thing holds good with a cylinder in the meridian of its power, i. e. across its axis.

If we look through a cylinder at a straight line, other than in alignment with the axis of the cylinder, or at right angles to it, the continuity of the line appears to be broken where it enters the range of the cylinder. By rotating the cylinder, as we look through it, until the straight line passes through unbroken, we know that this straight line now represents either the axis of the cylinder or its perpendicular. If the unbroken line be running along the axis of the cylinder, the refractive power of the cylinder will affect the thickness of the line, making it appear thinner in the case of a convex cylinder, thicker in the case of a concave, than where it is outside the range of the lens. If the unbroken line lie across the axis of the cylinder, no change will appear in its thickness. We are therefore able to find the axis of a cylinder by this means.

If, then, we hold a cylindrical lens upright, i. e. the way it is going to set before the patient's eye, and view through it an astigmatic wheel chart, we can see at once where the axis of the cylinder lies, by noting the meridianal line of the chart which passes unbroken through the lens, but is changed in thickness.

Lenses, as put up in a trial case for use, are numbered either according to their focal length or according to their dioptric power; sometimes according to both.

Lens Capsule. The capsule which surrounds and contains the crystalline lens. See **Lens, Crystalline.**

Lens, Crystalline. The lentel-shaped, transparent body which lies between the aqueous and vitreous humors of the eye, suspended all around by a circular ligament called the zonula ciliaris, formed by a reflection of the hyaloid membrane. The substance of the lens is arranged in layers, and consists of a nucleus and a cortical portion, enclosed in a fine capsule. In a young healthy person, lens and capsule are both exceedingly elastic; but this elasticity gradually diminishes during life, until, at about seventy years of age, it is lost altogether and the lens becomes rigid.

The lens has no blood supply, depending for nourishment upon the vessels at its periphery. Therefore, under certain conditions of internal disease and malnutrition, it easily becomes degenerated and opaque. This constitutes cataract.

Optically, the crystalline lens is a biconvex lens, whose front curvature, at rest, has a radius of 10 mm. and its posterior surface a radius of 6 mm., the latter having the greater curvature. Its index of refraction at the nucleus is 1.43; at the cortex it is less. Of itself, the lens has a dioptrism of 19 or 20 D., but in series with the rest of the refracting media of the eye this power is diminished. A plus 10 or 11 D. lens before the eye usually compensates for the loss of the crystalline lens.

The function of the lens, of course, is to help focus light upon the retina. In accommodation, the front surface is made more convex by contraction of the ciliary muscle. This faculty gradually diminishes as life advances, until it is finally lost.

Lens Measure. Since the index of refraction of crown glass lenses is uniform, the variant factor is the curvature of the lens, and any mechanical device for measuring this curvature

Geneva Lens Measure.

will determine the dioptric power of the lens. Such a device is accomplished by means of two immovable pins and a

movable central pin, the two former being held firmly against the lens, the latter pressed up in proportion to its convexity or allowed to project in proportion to its concavity. It is necessary, of course, to measure both sides of the lens, and to calculate their net result.

Lens Sizer. An instrument for measuring the size of the lens. Manufactured by the Merry Optical Company.

Lenses—Nomenclature—Biconvex, Biconcave, Concavo, Convex, Concave, Spherical, Convex Spherical, Cylindrical, Deltar, Korrectal, Meniscus, Plano Convex, Periscopic, Peritoric, Prism, Punktal, Toric.

Lenses—Nomenclature — (Bifocals) — Bisight, Bitex, Cement, Duplex, Genothalmic, Kryptok, Opifex, Perfection, Revelation, Ultex, Wellsworth Forty-Five and others.

Lenticonus. Cone-shaped curvature of the crystalline lens.

Lenticular. See lenses.

Lenticular. Pertaining to the crystalline lens.

Lenticular Astigmatism. Astigmatism due to irregularity in the curvature of the crystalline lens. (See **Astigmatism**).

Lentitis. Inflammation of the crystalline lens.

Leucoma. Leukoma. A white opacity on the cornea.

Levator Palpebrae. See **Muscles of the Eye.**

Levoduction. Rotation of one or both eyes to the left.

Ligament. A band of connective tissue which serves as an attachment or support. In the eye are the following:

Ciliary Ligament. Connects the cornea and sclerotic, at their line of junction, with the iris and external layer of the choroid.

Palpebral Ligament. Connects the cartilage of the lids to the orbit.

Suspensory Ligament, or Ligament of Zinn. A circular ligament attached to the optic foramen, from which arise the four rectus muscles and the superior oblique.

Light. This word has two applications. Objectively, light is a form of physical energy which, when it falls upon the retina and stimulates it, produces in the brain the sensation of vision. Subjectively, the word is applied to the sensation itself. This sensation manifests itself in two phenomena, (a) visibility, and (b) color, both of which will be found discussed under their respective headings. This article will deal wholly with the physical aspect of the subject.

NATURE OF LIGHT.

The precise nature of light is even yet unknown. Up to the beginning of the nineteenth century two theories of its mode divided the field, the corpuscular theory of Newton, and the wave theory of Christiaan Huygens; and although Huygens' theory (1690) preceded that of Newton (1704), the tremendous weight of Newton's authority and influence caused his theory to be generally accepted, in preference to Huygens', for many years.

Newton taught that luminous bodies emitted minute particles of matter, which passed freely through transparent substances, and whose impact on the retina produced sensation of light. He assumed these corpuscles to be subject to the same influences of attraction and repulsion that he had ascribed to matter in general, and to obey the same laws of motion. Thus in the interior of a homogeneous body, according to the first law of motion, a light corpuscle was held to move in a straight line, because it was acted upon equally upon all sides; but it changed its course at the boundary of two bodies, because in the thin layer near the surface there was a resultant force in the direction of the normal. Light was reflected, according to the well-known laws of reflection, if the corpuscles were acted upon by a sufficiently large force moving toward the first medium; otherwise it was refracted.

Huygens was the first to show that the explanation of optical phenomena can be made to depend upon the wave-surface, both in isotropic bodies, in which the surface of the wave is spherical, and also in crystals of double refraction. He deduced the famous Huygens principle, which is the foundation of our modern concept of light, namely, that "any point that is reached by a wave of light becomes a new centre of

radiation from which the disturbance is propagated in all directions."

The overthrow of Newton's corpuscular theory was contributed to by several inductive experiments in the early part of the nineteenth century, but its final doom was sealed by Foucault, who showed that the velocity of light was less in water than in air, which was in opposition to the corpuscular theory and in harmony with the wave theory. It must not be forgotten, however, that, in spite of the unsoundness of Newton's theory, he worked out some exceedingly valuable calculations regarding light, which are still valid.

PROPERTIES OF LIGHT.

Light has two important properties, (1) Intensity, and (2) Velocity. Intensity represents the amount of light packed into a given area, and, as between different sources of illumination, at a constant distance, depends upon the amount of energy represented in the light-production. For the same source of illumination, intensity varies with the distance from the point of origin; since, according to Huygens, the light wave is propagated equally in all directions (spherically), the ratio between light-activity and area undergoes a geometrical progression, so that intensity varies inversely as the square of the distance from the point of origin; which is the same as saying that it varies inversely as the square of the radius of the light-wave.

The velocity of light is a constant, so far as light itself is concerned, and varies only according to the density of the medium through which it travels. Propagated through luminous ether, its velocity is about 186,000 miles per second. Other substances offer varying degrees of resistance to its passage, and its velocity is increased or diminished, as the case may be, as it passes from one of these mediums into another. These changes in velocity bring about, under certain circumstances, a change in the curvature of the wave and the direction of its propagation, which constitutes the phenomenon of refraction. The difference in velocity is expressed in the ratio between the sines of the angles of incidence and refraction, respectively, plus or minus, as the case may be, as the light passes from one medium into another.

PHENOMENA OF LIGHT.

Upon coming in contact with any substance, light undergoes one or more of the following modifications:

(1) Reflection: it is turned back by the surface of the object or medium.

(2) Refraction: it passes into and through the substance or medium, undergoing changes of velocity and direction.

(3) Absorption: its waves are wholly or partially exhausted in passing through the substance, so that it does not emerge on the other side.

(4) Dispersion: it is broken up into its composite parts by refraction by a medium whose incident and emergent surfaces are not parallel to each other.

(5) Diffraction: it is split into its component parts by impingement on a sharp edge of a hard substance.

(6) Polarization: By double refraction through a bi-axial crystal.

Each of these phenomena of light is fully dealt with under its own heading, to which the reader is referred.

WAVE CURVATURE.

The ophthalmic refractionist deals almost wholly with the light waves of Huygens in isotropic media, whose curvature is spherical; and this quality of curvature, together with that of velocity, constitute the very foundation of eye refraction. The curvature of a wave varies inversely as its radius, and these two quantities are therefore reciprocals of each other. The unit of curve measurement, as used by the refractionist, is the curvature of a wave having a radius of 1 meter; this is known as the meter curve, or mc. All other curvatures are expressed in multiples or dividends of the meter curve or its radius. If r stands for the radius, then:

$$mc = \frac{1}{r}$$

SOURCES OF LIGHT.

Light that reaches us from the sun is called natural light; that which is furnished by artificial means is known as artificial light. There are two principal modes of producing artificial light, viz., combustion, as exemplified in the candle, oil

lamp, and gas flame, and friction, as seen in electric light. This aspect of the subject will be found discussed in the section on **Illumination.**

SUMMARY.

The theory of light may be summed up in the following propositions formulated by Thomas Young in his Bakerian lecture of 1801:

(1) A luminiferous ether pervades the universe, rare and elastic in a high degree.

(2) Undulations are excited in this ether whenever a body becomes luminous.

(3) The sensation of different colors depends upon the different frequency of vibrations excited by the light on the retina.

(4) All material bodies have an attraction for the etherial medium, by means of which it is accumulated in their substances and for a small distance around them in a state of greater density but not of greater elasticity.

(5) All impulses are propagated in a homogeneous elastic medium with an equable velocity.

(6) An undulation conceived to originate from a single particle must expand through a homogeneous medium in a spherical form, but with different quantities of motion in different parts.

(7) A portion of a spherical undulation, admitted through an aperture into a quiescent medium, will proceed to be further propagated rectilinearly in concentric superfices, terminated laterally by weak and irregular potions of newly diverging undulations.

(8) When an undulation arrives at a surface which is the limit of media of different densities, a partial reflection takes place, proportionate in force to the difference of densities.

(9) When an undulation is transmitted through a surface terminating different media, it proceeds in such a direction that the sines of the angles of incidence and refraction are in the constant ratio of the velocities of propagation in the two media.

(10) When an undulation falls on the surface of a rarer medium so obliquely that it cannot be regularly refracted, it is totally reflected at an angle equal to that of its incidence.

(11) If equidistant undulations be supposed to pass through a medium of which the parts are susceptible of permanent vibrations somewhat slower than the undulations, their velocity will be somewhat lessened by this vibratory tendency, and, in the same medium, the more as the undulations are more frequent.

(12) When two undulations from different origins coincide, either perfectly or very nearly, in direction, their joint effect is a combination of the motions belonging to each.

(13) Radiant light consists in undulations of the luminiferous ether.

EINSTEIN'S DOCTRINE.

Within the last year (1920) Albert Einstein, of Germany, has propounded the doctrine that light is possessed of mass, and is subject to gravitation, i. e., it is attracted by large bodies and deflected out of its straight path. He not only stipulated its deflection, but calculated the degree to which it would be deflected by a given mass and density of body; and this was verified both qualitatively and quantitatively by a commission of the Royal Society of Great Britain during the last solar eclipse.

Light Area. Term applied to the light thrown by the retinoscope on the face and in the pupil.

Limbus. The border-line between the cornea and the sclera.

Limbus Cornea. The junction of cornea and sclera.

Limit Angle. See **Critical Angle.**

Line of Fixation. See **Fixation.**

Line of Vision. A colloquial term for the visual axis.

Lippitudo. Same as **Blepparitis Marginalis.**

Lippus. Blear eyed.

Liquor Morgagni. A thin layer of fluid between the crystalline lens and its capsule.

Lithiasis. Calcarous deposits in secretion of the Meibomian glands.

Logadectomy. Removal of a portion of the conjunctiva with a knife.

Logades. The first tunic of the eye.

Loimophthalmia. Contagious ophthalmia.

Long-Sightedness. A common name for hyperopia, referring to the ability of the hyperope to see better at a distance than at near point.

Lorgnette. Folding eye-glasses attached to a handle.

Lorgnon. Same as lorgnette.

Lorgnon.

Louchettes. Opaque glasses with a small opening for each eye which forces the patient to look through this opening.

Loupe. A magnifying lens used for examining the eye.

Loxophthalmos. Strabismus.

Lucifugal. A condition in which the patient avoids bright light.

Luminous Body. A luminous body is one which is a source of light. They may be divided into natural and artificial. The sun is, of course, the only natural source of light known to us; candles, lamps, electric lights, are artificial luminous bodies.

The modern viewpoint, however, regards many reflecting bodies as luminous bodies, holding that they so change the quality of the light waves that strike them as to become practically sources of new light waves. Thus, we can certainly regard the moon as a true luminous body, although its light is reflected from the sun. In the same way, we regard the retina as a true source of light in our retinoscopic and ophthalmoscopic work.

Luxatio Bulbi. Avulsion of the eyeball.

Luxation. Another word for dislocation. In ophthalmology it refers to a dislocation of the crystalline lens.

Lymph. A fluid in the body which forms an intermediary between the blood and the tissues which the blood is to nourish, and may be regarded as a sort of reservoir for the nutriment which the blood brings to these tissues and also for the waste substances which the tissues give up for the blood-stream to remove. Through this fluid, therefore, the exchange between the blood and the tissues is constantly taking place. It is a colorless, transparent fluid, contained in a system of vessels and glands, very similar to the system of blood-vessels, and is eventually poured into the venous system by means of a large lymph-vessel called the thoracic duct, near the heart.

Lymphadenoma. A tumor of the lymphoid tissue.

Lymphatics. A general name given to the system of vessels and glands concerned in the elaboration and transportation of lymph. The lymphatic glands are very important structures, for it is only after passing through them that the lymph is ready and fit to enter the blood. Their average size is that of an almond, and they are usually arranged in groups; but many of them are very much smaller. The lymphatic vessels which absorb nutriment from the intestines are called the lacteals. The eye, of course, has its lymphatic system.

Macrocornea. Megalocornea. Cornea of abnormal size or projection.

Macrophthalmus. Indicating unusually large eyes.

Macropsia. A condition in which objects appear larger than normal.

Macroscopic. Large enough to be seen with the naked eye.

Macula Lutea. The yellow spot. The most sensitive spot of the retina, situated about a disc diameter from the disc, toward the temporal side. It appears yellow because it is devoid of vessels, so that the pigment of the chorioid shows uninterruptedly.

Optically, the yellow spot is the center of the visual field

on the retina. Only that portion of an object which is represented by foci on the yellow spot is viewed with attention. It is the yellow spot which is directed toward an object in fixation, and a line from the yellow spot to the object constitutes the visual axis.

In the center of the macula is the fovea centralis, the most sensitive point in the macula.

Madarosis. Complete destruction of the eye-lashes.

Maddox Rod. An apparatus devised by Dr. Ernest Maddox, of England, for testing muscular imbalance. It consists of an opaque disc with a glass rod set in it, which draws out the

Maddox Rod.

image of a candle-flame or circular light into a streak at right angles to the rod, so as to dissociate it from the image seen by the other eye. For description of its use see **Heterophoria.**

Madisterium. An instrument for removing eye-lashes.

Magnification. Magnifying Power. The ratio between the angle subtended by the object at the center of the entrance-pupil of a lens system and the linear dimension of the image, in favor of the image.

Intrinsic Magnification. The ratio between the visual angle subtended at the nodal point of the eye by the image viewed through the magnifying instrument and the corresponding linear dimension of the object.

Objective Magnification. The ratio of the linear size of the image to the apparent size of the object.

Subjective Magnification. The ratio of the visual angles or

their tangents subtended at the nodal point of the eye; this ratio involves the distance of distinct vision.

Magnify. To increase the apparent size of an object.

Malacocataract. A soft cataract, usually traumatic, occurring in persons under forty.

Malaxation. Massage of the eye.

Malignant. Tending to fatality.

Malingering. Pretending to some form of sickness, or physical or mental defectiveness, usually for some interested purpose, such as avoiding military service, recovering damages for an alleged injury, etc. In ophthalmology malingering generally implies the pretense to some degree of blindness or defective vision. There are many tests for the detection of such malingering, of which the following are the most commonly employed:

Bar Test. A pencil or other similar object is interposed between the patient's eyes and reading type at a suitable distance. If he is reading with one eye only, this will shut off a part of the type; but if he is using both eyes, he can read around it.

Convex Lens Test. A convex lens of 6 D. is placed before the sound eye. This places the far point at about 16 cm. A reading chart of suitable type is held well within this far point, and the patient required to read aloud. As he reads, the chart is gradually withdrawn beyond the 16 cm. If he still continues to read the letters, it is evident he is doing it with the other eye.

Prism Test. While the patient is reading, with both eyes open, we make a show of concerning ourselves with the sound eye. As he reads, we slowly interpose a prism, about 4 dioptres, base up, before the sound eye, gradually pushing it upward in front of the eye, until its base cuts the center of the pupil. This produces monocular diplopia, to which the patient will readily assent. Continuing the test, we push the prism still further up until it covers the sound eye. There will now be no more monocular diplopia, but binocular diplo-

pia. If, therefore, the patient still admits double vision, he is reading with both eyes.

Complementary Color Test. Snellen's test type, with letters alternately red and green, is used. A green glass is placed before one eye and a red glass before the other, in the trial frame. The green glass blots out the red letters, being complementary colors, and the red glass the green letters. If, therefore, the patient reads all the letters, it is evident that both eyes are in vision.

Black and Red Test. A variation of the above test is to use alternately black and red letters on a white background. A red glass is placed before the sound eye, which makes the background substantially the same color as the red letters. The patient is made to read the letters rapidly, and if he reads them all, it is evident that he is doing so with the alleged poor eye.

In any of these tests the patient, if he be shrewd, may fool the examiner by slyly closing the alleged poor eye for a moment and getting an idea how the chart ought to be read. We can meet this by suddenly placing a 4 dioptre prism, base up, before alleged poor eye, while he is reading aloud with both eyes open. If the eye be really poor, the prism will have no effect and he will read right on; if it be a good eye, the sudden doubling of the images will confuse him in his reading.

Mann's Sign. Condition in exophthalmic goiter when two eyes do not seem to be on a level.

Marginal. Occurring at the margin of an area.

Marginal Blepharitis. Inflammation of the margin of the eyelid.

Marginal Keratitis. Inflammation around the margin of the cornea, occurring in old persons.

Mariotte's Blind Spot. The optic disc.

Mariotte's Experiment is the demonstration of the blind spot by means of a dot and a cross, several inches apart, on a card; as the card is moved to or from the eye, with the eye fixed on the dot, the cross becomes invisible at a certain distance, proving the existence of the blind spot.

Marmarygea. Appearance of sparks before the eyes.

Mature. Fully ripe; applied to a cataract.

Mechanics of Fitting Eyes. See **Frame Fitting.**

Median. A technical term for middle.

Median Line. In physiologic optics usually applied to the line drawn perpendicularly to that which joins the geometric centers of the two eyes.

Medium. In optics this word specifically designates a body or substance through which light passes and by which it is influenced in passing—principally refracting bodies or substances,—as distinct from their surfaces.

The media of the eye are the cornea, the aqueous humor, the crystalline lens and the vitreous.

Megalocornea. Bulging of the cornea.

Megalophthalmos. An unusually large size of eye.

Megalopsia. A condition in which objects appear larger than they really are.

Meibomian Glands. Acinous glands embedded in the tarsal bodies of the eyelids. They secrete an oily (sebaceous) fluid which serves to lubricate the lids and the eyeball.

Melanin. A dark pigment of the choroid.

Melanocataracta. Black cataract.

Melanophthalmous. Melanoma of the eye. Black eyes. In botany indicates spots surrounded by black circles, resembling eyes.

Melasma Palpebrarum. Discoloration of the eyelid.

Meliceris. Chalazion.

Membrane. A thin covering tissue.

Capsular Membrane. A vascular network over the posterior surface of the lens.

Nictating Membrane. An extra eyelid, seen in birds and other lower animals.

Pupillary Membrane. A membrane covering the pupil in fetal life, which occasionally persists.

Meniscus Lens. See **Lens.**

Menotyphlosis. Diminution of vision during the night.

Meramaurosis. Partial amaurosis.

Meridian. The word is derived from a Latin word meaning pertaining to the south, or midday, and was originally applied to an imaginary line drawn around the earth from the north pole through the south pole. It was later extended to mean any imaginary line drawn around a sphere, so as to divide it equally, in any of the 360 angular directions. Also to diameters of a circle at any of these angles.

As we usually represent a sphere, diagrammatically, by a plane circle, so also we represent its meridians as meridians of a circle. They are numbered from the left-hand extremity of the horizontal equator in the direction of the figures on a clock-dial, the extreme left of the equator being 0, the vertical 90 degrees, the extreme right of the equator 180 degrees, the lower vertical 270 degrees, etc.

As to the significance of the meridians of the cornea in astigmatism, see **Astigmatism.**

It should be borne in mind, in subjective testing, that the meridians on either side the vertical on the test-chart represent meridians on the opposite side of the cornea.

Meropia. See **Amblyopia.**

Mesiris. Substantia propria of the iris. The middle layer.

Mesoretina. The middle layer of the retina.

Mesoropter. The position of the eyes in a state of rest.

Mesoseme. Having a medium orbital index of 85 to 90.

Metamorphopsia. A condition in which objects appear distorted.

Meter Angle. The angle made by the visual axes with the middle perpendicular line. See **Convergence.**

Meter Curve. The curvature of a sphere, or segment thereof, having a radius of 1 meter. The unit of curvature in optical mathematics.

Metric System. Also called Decimal System. A system of weight, measure, and money, in which the unit is multipled by 10 or some power of 10 to give the higher denomination, and divided by 10 or a power of 10 to give the lower denominations.

So far as optics is concerned, the metric system is a decimal method of lineal measurement, of which the meter is the unit (being equal to 39.371 inches). Latin prefixes are used to denote dividends of the meter, and Greek prefixes to indicate multiples, as follows:

Decimeter....A tenth of a meter.
Centimeter....A hundredth of a meter.
Millimeter....A thousandth of a meter.
Decameter....Ten meters.
Hektometer...One hundred meters.
Kilometer.....One thousand meters.

The metric system of weights and measures is used almost entirely by scientists, because of its simplicity, and the ease with which it adapts itself to unit calculations. In optics this is readily seen in the reciprocity between the radius and the curvature of a light wave, and between the focal length and dioptric power of a mirror or lens.

Meyer's Rings. Rings of violet or blue seen around a candle flame against a dark background, due to diffraction.

Microblepharism. Smallness of the eyelids.

Microcornea. An exceptionally small size of the cornea.

Microlentia. An unusually small size of the crystalline lens.

Micrometer. An instrument for measuring very small arcs in the field of the telescope, and for making very small linear measurements in other departments of physics.

Micron. One [illegible] part of a millimeter.

Microphakia. An unusually small size of the crystalline lens.

Microphthalmia. Abnormal smallness of the eyeballs.

Micropsia. A condition in which everything appears smaller than normal.

Microscope. An instrument for magnifying the image of minute objects. It consists of a combination of lenses, and in some cases of mirrors also, one lens, or combination of lenses forming the objective, to magnify the image, and one lens forming the eyepiece, for focussing the magnified image on the observer's retina. The principle of magnification is that the relative sizes of object and image are directly as their relative distance from the optical center of the objective lens. Thus the magnifying power of a microscope can be increased by (1) increasing the strength of the objective lens, (2) increasing the power of the eyepiece lens, or (3) increasing the distance between objective and eyepiece.

Milium. A seed-like elevation under the skin of the eyelid.

Milphae. Dropping out of the eyelashes.

Milphosis. Falling out of the lashes and eyebrows.

Minus. A negative quantity, i. e., less than nothing. As applied to optics, it denotes a wave-curve or a lens-power whose surface is concave.

Mirror. A polished surface which reflects practically all the light that strikes it. Such a reflecting surface may, of course, have any kind of configuration, regular or irregular. In optics we have to do with plane and curved mirrors; and in elementary optics the curved mirrors are spherical, either convex or concave.

Plane mirrors merely change the direction of propagation and turn the front of the light waves that strike them; they exercise no influence upon the curvature of the waves.

Spherically curved mirrors add twice their own curvature to the curvature of the light wave that strikes them, as well as turning their front and changing the direction of their travel. Thus, a concave mirror, adding twice its own curvature (which is minus) to a neutral wave, turns it into a minus wave of

twice its own curvature, and brings it to a focus in half the radius of the mirror. The focal length of a mirror, therefore, is half its radius; and its dioptrism is twice its physical or meter curve.

If the wave that strikes a concave mirror comes from a point within infinity (a plus wave), the mirror adds its dioptrism to the wave, which turns it into a minus wave equal to the dioptrism of the mirror, less its own plus curvature when it struck, and brings it to a focus at a distance corresponding to the radius of curvature of the wave when it leaves the mirror. Thus, if the wave originates 50 cm. from a 2.50 D. concave mirror, it will be a plus 2 D. wave when it strikes the mirror; the mirror will add minus 2.50 D. to it, making it a minus .50 D. when it leaves, and it will focus at 2 meters (which is the radius of a .50 D wave) in front of the mirror.

If the wave originates at the spherical center of the mirror, the reflected wave will be so curved as to trace exactly the same path as the incident wave, and the object and the image will occupy the same point in space.

If the incident wave originate nearer to the mirror than its own focal length, the mirror can no longer turn it into a minus wave, but only reduce its convexity.

The image formed by the reflection from a concave mirror is, therefore, a real, inverted image of the object if the latter lie outside the optical center of the mirror; identical with the object if the object lie at the center; and a virtual, upright image if the object lie inside the focal length of the mirror.

A convex mirror, adding its own dioptrism to a light wave, cannot bring either neutral or convex waves to a focus, but renders them still more plus by just its own dioptrism. For the purposes of measurement, however, such waves, as they leave the mirror, are projected backward to the point from which they appear to have originated, and this is said to be their negative focus. Convex mirrors thus have negative focal points, and virtual images. They do not exist except in the mathematician's mind. Their mathematical relations, however, are the same as in the case of concave mirrors, except that the negative points all lie behind the mirror instead of in front of it.

Real images are conjugate with the objects they reproduce, because if the situation were reversed, and the object were placed where the image is, the image would be made in the place where the object is. Virtual images, of course, are not conjugate with any point, because they do not really exist. If the object were placed where a virtual image is supposed to be, an entirely different set of optical conditions would be created.

From what has been said, it will be seen that the dioptric power of a spherical mirror is twice its metric curve, which it adds to the light wave that strikes it.

When light falls on a spherical mirror beyond a certain acuteness of angle it is not reflected in accordance with the laws of reflection.

(See **Reflection.**)

DOUBLE MIRRORS.

If two plane mirrors be opposed to each other, with their surfaces parallel, and a luminous point between them, the number of images formed is infinite, all lying upon a line passing through the luminous point and perpendicular to the mirrors.

If two plane mirrors, with their surfaces opposed, be inclined at an angle, then it is evident that the line on which the images lie is not a straight line, but the arc of a circle, whose center is the point of intersection of the two mirrors and whose circumference passes through the luminous point. The number of images is now manifestly limited, for when any image falls in the arc lying between the planes of the two mirrors produced beyond the point of intersection, this image lies behind both mirrors, and hence no further image is possible. The arc in question is, of course, equal in angular measurement to the arc between the two mirrors, and the portion of it which is "dead" for each mirror, respectively, is equal to the portion lying between the mirror in question and the luminous point. If θ stands for the angle of separation, d for the distance between object-point and mirror, and π for the value of two right angles, then the number of possible images for each mirror is represented by the integral number next greater than $(\pi - d)/\theta$.

If π/θ be itself an integral number, then the number of images for each series is π/θ, but an image of each series coincides; hence the number of images, including the object-point, is $2\pi/\theta$.

Thus, if two mirrors be inclined at an angle of 70 deg., and the object-point be 20 deg. from one surface and 50 deg. from the other, the number of images in the first series will be equal to $180 - 20/70 +$ sufficient to make the next greater integer, i. e., 3; in the second series, $180 - 50/70$ plus enough to make the next integer, i. e., 2; total number of images, 5.

If the angle of inclination be 60 deg., then π/θ is itself an integer, and the number of images will be $360/60 = 6$, including the object-point, or 5 true images. Advantage is taken of this latter principle in the construction of the kaleidescope, in which 7 images are produced by an inclination of 45 deg.

Miosis. Forced contraction of the pupil by means of a drug. The two drugs commonly used for this purpose are eserine (or physostigmine) and pilocarpine. Contraction of the pupil is brought about by contraction of the sphincter iridis muscle; and both these drugs put this muscle into a state of tonic contraction. It should be borne in mind that they also affect the ciliary muscle in the same way, producing an artificial accommodation.

Miotic. A drug that produces miosis. See above.

Moebius' Disease. Periodic paralysis of the muscles of the eye, with migraine.

Monoblepsia. A condition in which the sight of one eye is much better than that of both together.

Monocentric. Originating from one center. Same as **Homocentric.**

Monochromasia. Color-blindness to all but one color.

Monochromatic. Applied to a beam of light in which there is but one length of wave.

Monochromatic Aberration. Spherical aberration. See **Aberration.**

Monocle. A single eyeglass.

Monocular. The terms refers to any function or appliance in which one eye alone participates.

Monocular accommodation. The accommodation exerted when only one eye is in vision.

Monocular diplopia. Double image seen with one eye alone. Usually due to astigmatic facets on the cornea.

Monocular squint. Deviation of one eye only.

Monocular vision. Vision with one eye alone.

Monops. A monster with only one central eye.

Moon-Blindness. A rare form of retinal blindness due to sleeping in the bright tropical moonlight.

Morgagnian Cataract. A cataract which has shrunk so that there is a layer of fluid between the lens and its capsule.

Morgagnian Humor. A thin layer of fluid supposed to lie between the crystalline lens and its capsule.

Mucocele. Any distension of a sac as of the lacrymal sac.

Mueller's Muscle. The sphinctre muscle of the eye.

Murine. Proprietary eyewater popular with the public.

Muscae Volitantes. Floating spots seen subjectively. They are the projection of minute particles in the vitreous humor. They may be normal or pathologic. Myopes frequently see them, because of the abnormal length of the eye-ball. See **Entoptic.**

Muscle Exercises. The exercising of muscles, in general, can be divided into two classes, (1) sheer physical exercising of the muscle itself, for the purpose of increasing its bulk and power, and (2) exercising of the co-ordinating faculty of physiologic groups of muscles.

In prescribing and carrying out exercises of the extrinsic muscles of the eyes, for the cure of imbalance or squint,—es-

origin anterior to the cornea. The far point of this eye is, therefore, 50 cm. from the surface of the cornea.

THE FAR POINT.

Clinically the myopic far point is determined by the same method as that of the hyperope; that is to say, subjectively by means of the Snellen chart, objectively by means of static retinoscopy.

The myope's far point being inside of infinity, he cannot read 20/20 by any means at his command. He reads only the type whose minimum visual angle at 6 meters or 20 feet corresponds to the angular aperture represented by his far point; and the number of this type as a denominator, with the normal number as a numerator, expresses, in the form of a fraction, his distant vision. If he reads at 6 meters the type which an emmetrope reads at 8 meters, his vision is 6/8, or 3/4, or if he reads at 20 feet the type an emmetrope can read at 30 feet, his vision is said to be 20/30.

To enable a myope whose vision, let us say, is 20/40, to read the 20 type at 20 feet, we must make the 20 type subtend a visual angle at his nodal point equal to the angle which the 40 type now subtends. Translating this into refraction, this means that we must, by means of minus lens power, diverge the neutral light waves proceeding from the chart so that they fall upon his cornea with a plus curvature normal to his eye, i. e., equal to the reciprocal of his far point. The lens which does this is the measure of his myopia; or, what is the same thing, his far point divided into unity is the measure of his myopia in dioptres.

In static retinoscopy, with a plus lens before the patient's eye, we shall always find the myope's point of reversal nearer to the eye than the focal length of the working lens. The calculation is made in the same manner as in hyperopia, i. e., the difference between the place where it ought to be and the place where it is, in terms of reciprocals, gives us, also in terms of reciprocals, the patient's far point. In the case of the myope, since the latter quantity is always greater than the former, the result is a negative quantity, indicating that the point is short of infinity.

Thus, if with a plus 2 lens we find the point of reversal at 25 cm., whereas it ought to be at 50 cm., then:

$$\frac{1}{.50} - \frac{1}{.25} = \frac{-1}{.50}$$

which is to say, the patient's far point is at 50 cm., (between the eye and infinity), and he is 2 D. myopia.

THE NEAR POINT.

The myope's near point is determined by precisely the same means as that of the emmetrope or hyperope, namely, by Scheiner's test, by Jarger type, or by dynamic skiascopy. It is, of course, much further in than that of the emmetrope, corresponding to the nearness of his far point. It is, in fact, usually so much nearer to the patient's eyes than he has any occasion to accommodate that it has no particular working value in itself, being useful only for purposes of calculation.

AMPLITUDE OF ACCOMMODATION.

According to the formula previously given, the subtraction of the far point from the near point, in terms of dioptrism, gives us the myope's amplitude of accommodation. Myopes of moderate degrees of error usually have fairly normal amplitude of accommodation; and, as they do not have to use any of their accommodation until well within infinity, they possess a greater amount of available accommodation than the emmetrope by just the amount of their myopia. Thus, if a myope's far point be at 50 cm., and his near point for ordinary work at 25 cm., he uses only

$$\frac{1}{.25} - \frac{1}{.50} = \frac{1}{.50}$$

that is, 2 D. of accommodation for this working point, whereas the emmetrope must use

$$\frac{1}{.25} - \frac{1}{\text{inf.}} = \frac{1}{.25}$$

that is to say, 4 D. for the same point, giving the myope an advantage of 2 D. available accommodation.

ACCOMMODATION-CONVERGENCE RELATION.

Mathematically, myopia carries with it precisely the same proportional amount of accommodation-convergence discrepancy, dioptre for dioptre, as hyperopia; for, while every dioptre of hyperopia represents excess accommodation, every dioptre of myopia represents the same amount of excess convergence. Physiologically, however, the state of affairs is altogether different. The abnormal relation in myopia is, so to speak, a negative or passive condition. The two functions do not actively clash, as in hyperopia; one of them simply "lays off." Lacking accommodation stimulus to bring his convergence into play, outside his far point, the myope simply replaces it altogether with fusion stimulus; inside his near point he makes up, with fusion stimulus, the deficit in his accommodation stimulus. As he uses neither accommodation nor convergence at infinity, there is nothing to cause a development of muscular imbalance at that point. This whole matter will be found fully discussed in the chapter on Heterophoria.

When we come to consider the state of affairs at the myope's near point, the same thing holds true. Myopes of moderate degrees usually have fairly normal amplitude of accommodation; and, as they do not begin to use their accommodation until well within infinity, they have, as a rule, more available accommodation than the emmetrope by just the amount of their myopia. Add to this the fact that the point at which the average myope does his near work is far from being his maximum near point, and it will readily be seen that he has plenty of accommodative reserve.

For these reasons, in spite of the break in his accommodation-convergence ratio, the average myope has none of the troubles, either at far point or at near point, that plague the hyperope; he seldom suffers from any muscular asthenopic symptoms; nor do we encounter the sources of error in refracting a myope that we meet in refracting the hyperope. The correction of his myopia establishes normal relations between accommodation and convergence,—which may bother him for a little while, but to which he soon adjusts himself, since his reserve and flexibility are ample. An exception must be made

in the case of high myopes, concerning whom more will be said presently.

SUMMARY.

The course of procedure in examining and prescribing for average degree myopes, therefore, is exceedingly straightforward and simple. Ordinarily, all that is required is to find their far point for each eye, which is equivalent to determining their myopic error for distance, and to furnish them with distance correction for constant wear.

1. Make a subjective test with the Snellen chart at 20 feet, adding successively stronger minus lenses until the patient reads 20/20. As the patient is already "in the fog," when the test is begun, on account of his own myopia, this test amounts to an application of the fogging method.

Special care should be taken to include the wheel chart in the procedure, to discover any possible astigmatism; for most myopes are also astigmatic.

2. Determine the refraction by static retinoscopy.
3. Make a test for muscle imbalance at near point.

This muscle test will usually disclose considerably more exophoria than in the emmetrope; but this is because most of the myope's convergence is fusion convergence, and is readily surrendered under the test. Unless, therefore, it exceeds 12 prism dioptres at 25 cm., or the patient is complaining of asthenopia, it need not be regarded. If it exceeds 12 prism dioptres, or if it gives definite reading trouble, it had better be corrected with prisms, base in, up to a point of comfort.

In the average case of moderate degree myopia it is not necessary to explore the near point at all. If the myopic patient is also presbyopic, his presbyopia must, of course, be investigated and corrected as in the case of any other presbyope (see Presbyopia). If he show symptoms of accommodative inefficiency, this must be explored by the same means and according to the same rules laid down in **Hyperopia.**

HIGH MYOPIA. PROGRESSIVE MYOPIA.

Most of the troubles which we encounter in dealing with myopes are furnished by cases of high myopia. Practically all of these cases represent a pathological condition of the eye.

Indeed, some regard myopia as being **per se** a pathological state, representing the attempt of nature to adapt the eye to near vision required by the exigencies of civilized life. The author does not share this view; but it is, of course, beyond question that the physical conditions attending myopia—the elongated eyeball, the tense chorioid, the necessity for poring over one's work—are such as may very easily cross the borderline from functional to organic trouble. And in almost every case of high myopia, the line has been crossed.

The most serious feature of this pathology is the damage done to the chorioid. The ophthalmoscope shows a crescentic white patch of atrophy on the macular side of the disc, where the greatest amount of stretching takes place; and often it reveals, also, patches of chorioidal degeneration. In very high degrees of myopia the epithelial layer of the retina atrophies and secondary changes may occur in the macula itself. All of these diseased conditions are prone to increase year by year—sometimes even from month to month—constituting what is known as "progressive myopia," so that, ultimately, the vitreous may become disorganized, cataracts form, chorioidal hemorrhages occur, and retinal detachment take place.

From an optical standpoint, the chief difficulties in the way of satisfactorily correcting high-degree myopes are:

1. In extreme degrees of myopia the high-power minus lenses necessary for full distance correction usually reduce the size of the image on the retina to such an extent that the patient is unable to recognize objects. It is, therefore, impracticable, as a rule, to give these patients full correction for distance; we are obliged to guide ourselves by the amount of correction which gives the best possible vision.

2. The ciliary muscles, sharing in the general poor nutrition of the eye, and by reason of disuse, are greatly atrophied; often the circular fibres are lacking altogether. As a result, the patient has no accommodative power, so that, if full distance correction be given, or even sufficient distance correction to bring the far point outside of the patient's reading distance, he is unable to see at that reading distance. He is, in fact, a presbyope with his distance correction on. For this reason, it is necessary to give such patients separate glasses for distant

and near vision, subtracting from the distant lenses the reciprocal of the distance at which the patient wishes to read and prescribing the remainder for reading glasses.

3. The elongation of the eyeball, with its consequent equatorial distortion, makes the action of the internal rectus muscles in convergence exceedingly difficult. This embarrassment usually results in one of three eventualities:

(a) The patient continues to endure the situation, and to perform his convergence under difficulty, suffering meanwhile from eyestrain, until exophoria results in divergent squint, or,

(b) He substitutes for convergence the practice of making a conjugate turn of the two eyes, which also produces at length a divergent strabismus, or,

(c) He avoids convergence by using one eye only for his near work, and as he usually selects one eye (the dominant eye) for continuous duty, the other, unused eye ultimately becomes amblyopic.

This muscular trouble, with its train of mischievous consequences, is best remedied, and the consequences headed off, by the intelligent application of prisms, base in, for near work, up to the point of comfort and efficiency.

Myopic Crescent. A crescent-shaped area of white seen at the temporal side of the optic disc in high myopia. It is caused by the stretching and thinning of the chorioid, permitting the sclera to show through and reflect a white light from the ophthalmoscope.

Myosis and **Myotic.** Same as **Miosis** and **Miotic.**

Myospasm. Spasm of a muscle.

Myotomy. The cutting or dividing of a muscle.

Myotonic. Pertaining to muscle spasm.

Nagel's Test. A test for color-blindness with confusion colors printed in concentric circles.

Nasal Duct. That part of the tear duct which passes through the malar bone and into the nose.

Near Point. The nearest point for which the eyes are able to accommodate (near point of accommodation) or converge (near point of convergence). See **Accommodation** and **Convergence.**

Near Sight. A colloquial term for myopia.

Nebula. Tiny scattered opacities on the cornea.

Needling. An operation for soft cataract. The needle is introduced through the cornea, and the anterior surface of the lens pierced in several places, or torn by the needle. The action of the aqueous humor then causes the cataract to swell up and be absorbed.

Negative. In physical, including optical, science, this term is applied to a phenomenon, or a quantity, which occurs, or has its value, in a direction opposite to that of the phenomenon or quantity toward which it is said to be negative.

Negative Accommodation. It is supposed by some that when the ciliary muscle is adapted for infinity it is still capable of a slight further relaxation. This additional amount of relaxation is known as negative accommodation.

Negative After-Images. After-images which are the result of retinal exhaustion by the primary image.

Negative Convergence. Turning of the visual axes outward beyond the parallel.

Negative Crystals. Crystals of double refracting property in which the refraction of the ordinary ray is greater than that of the extraordinary ray.

Negative Focus. An imaginary focus arrived at by projecting divergent waves back to their apparent point of origin.

Negative Image. The virtual image made by negative focussing.

Neotocophthalmia. See **Ophthalmia Neonatorum.**

Nephablepsia. Snow-blindness.

Nephelopia. Cloudy vision.

Nephritic Retinitis. Same as **Albuminuric Retinitis.** See **Retinitis** and **Ophthalmoscope.**

Neurasthenia, Optic. A nervous condition in which the visual field is narrowed.

Neuritis, Optic. Inflammation of the optic nerve. When the part of the nerve back of the eyeball is involved it is called retro-bulbar neuritis. Under the ophthalmoscope it shows as a reddened, congested condition of the nerve-head (disc).

Neurochorioiditis. Inflamed condition of the chorioid coat of the eye and the optic nerve.

Neurochorioretinitis. Inflamed condition of the chorioid coat of the eye, the retina and the optic nerve.

Neurodealgia. Excessive sensibility of the retina.

Neurodeatropia. Atrophy of the retina.

Neuroretinitis. Inflammation of both the optic nerve and the retina. Both the disc and the surrounding retina are reddened and congested, with minute hemorrhages into the retina.

Neurospongium. Collection of fibrils supporting the neuroplasm.

Neutral. In optics this term is applied to light waves which have no curvature, and whose rays of direction are parallel. They are also called parallel waves. As they appear to have come from no point, and to be going to no focus, they are further known as infinite waves.

Neutralize. To render a plus or a minus light wave neutral, i. e., to rob it of its plus or minus curvature, so that it appears to have come from infinity.

The word also technically signifies to determine the dioptric power of a lens by placing in apposition with it a lens of the opposite curvature which neutralizes the parallax movement. (See **Lens**). In neutralizing with the trial case there is always a slight amount of error, due to the impossibility of obtaining exact apposition of the surfaces. The convex neutralizing lens should always be held next to the observer's eye.

Nictitition. Involuntary twitching of the eyelids.

Night Blindness. See **Blindness.**

Niphablepsia. Same as **Nephablepsia.**

Nodal Points. Two points in a lens, or lens system, on the principal axis, so situated that oblique rays, which enter and emerge from points whose tangents are parallel to each other, directed toward one, will appear to come from the other, after lateral displacement. (See **Lens**).

Mathematically, the nodal points are two conjugate points from which object and image appear under the same angle.

Normal. Physiologically, this word signifies conformance to the natural order of things. Optically, it is applied to a straight line which strikes a curved surface perpendicularly to its tangent.

Nubecula. Cloudiness of the cornea.

Nuclear. Pertaining to the centre of an organ.

Nuclear cataract. One which begins in the centre, or nucleus, of the crystalline lens.

Numeration of Lenses. See **Lens.**

Nyctalopia. Night blindness.

Nyctotyphlosis. Blindness at night-time.

Nystagmograph. An instrument for registering the movements of the eyeball in nystagmus.

Nystagmus. Rapid, involuntary oscillations of the eyeball. Usually due to central nervous disease. It is termed vertical, lateral, or rotary nystagmus, according to the direction of the oscillations.

Aural Nystagmus. Spasmodic nystagmus due to disturbances in the internal ear.

Miner's Nystagmus. Nystagmus occurring in coal miners, due to wielding a pick while lying on the side in a cramped position. When this nystagmus occurs upon turning the eyes downward, it is called miners' nystagmus against the rule.

Labyrinthine Nystagmus. Same as aural nystagmus.

Obcecation. Partial blindness.

Obfuscation. Obscuring of the vision.

Object. In optics this name is given to a body or area from which waves of light originate that are focussed upon the retina for the purpose of vision. The object and the image are conjugate with each other. (See **Lens**).

Object Blindness. Mind blindness.

Object Line. A straight line in the object-space containing the optical axis of a lens-system. With reference to the eye, a straight line between the nodal point and the object, connecting the object with the macula.

Object Plane. The plane, perpendicular to the axis, in which are situated the constituent points of an object in a lens system.

Object Point. Any one of the constituent points in the object plane as described above.

Object Space. The space traversed by the effective rays originating in the constituent points of the object in a lens system. See **Collinear Space System.**

Object Test-Card. A test chart for illerates and children, with objects instead of letters.

Objective. Physiologically, this term signifies a phenomenon, or set of phenomena, which are viewed and considered as being outside of and separate from one's own body, as distinct from subjective phenomena, which form a part of one's own sensations.

Objective symptoms. Symptoms which the observer demonstrates, as distinct from those felt by the patient.

Objective tests. Tests which depend upon the observer's findings, apart from the patient's information, such as retinoscopy.

Optically, the word objective is applied to a reflecting or refracting system whose purpose is to form an image of an object, which image is, in its turn, to serve as an object for further focal imaging.

Oblique. Making an angle with the perpendicular.

Oblique astigmatism. Astigmatism in which the chief meridians are neither vertical nor horizontal.

Oblique axis. An axis off the perpendicular.

Oblique illumination. Illumination of an object on one side, by passing the light obliquely through a lens.

Oblique Muscles. The muscles which move the eyeball obliquely.

Occipital. Pertaining to the back part of the head and the muscles which are attached to it. These muscles are usually fatigued in astigmatic patients, giving an occipital headache.

Occipito-Frontalis. The muscle, originating in the occiput and inserted into the fascia of the eyebrows, which lifts them upward.

Occlusion. Blocking the pupil by a membrane, as in iridocyclitis.

Ocellus. Having a single eye.

Ocular. Pertaining to the eye.

Ocular Spectres. See **Muscae Volitantes.**

Oculist. A medical practitioner who specializes in disorders and diseases of the eye.

Oculo-Motor. A term applied to the third cranial nerve because it mediates movements of the eye.

O. D. Abbreviation for Oculus Dexter, the right eye.

Offset Guard. A guard on an eyeglass for the purpose of holding the lens further from the eye. See **Spectacles.**

Old Sight. A colloquial term for presbyopia.

Onyx. Pus between the layers of the cornea.

Opacity. Imperviousness to the passage of light. Opacities of the eye are practically always either corneal or lenticular.

Opaque. Impervious to the passage of light.

Operculum Oculi. The eyelid.

Ophryitis. Inflammation of the eyebrows.

Ophrys. The eyebrow.

Ophthalmagra. Sudden pain in the eyeball.

Ophthalmalgia. Same as above.

Ophthalmia. Severe infection of the entire eye.

Ophthalmia Neonatorum. A form of purulent conjunctivitis which attacks newborn children, due to infection, usually with gonorrheal germs, during their passage through the birth-canal. In order to guard against its occurrence, most States have enacted a law requiring the attending surgeon or midwife to instill into every baby's eyes at birth a weak solution of silver nitrate.

Ophthalmitis. Same as **Ophthalmia.**

Ophthalmoblennorhea. Profuse flow of pus from the conjunctiva.

Ophthalmo-Carcinoma. Cancer of the eye.

Ophthalmocele. See **Stapyloma.**

Ophthalmocopia. Fatigue of the eyes.

Ophthalmodynia. Neuralgic pain in the eye.

Ophthalmography. Descriptive lore of the eye.

Ophthalmologist. One who is learned in the science of the eye and all that pertains to it. The word is commonly used interchangeably with "oculist," but it is really a much broader term. There are many ophthalmologists who are not oculists.

Ophthalmology. The science of the eye and all that pertains to it.

Ophthalmomacrosis. Enlargement of the eyeball.

Ophthalmomalacia. Abnormal softness of the eyeball.

Ophthalmometry.

*The ophthalmometer is, without doubt, a much abused and consequently a much disused instrument. It is probably true that a discussion of ophthalmometers and ophthalmometry in a group of men interested in refraction would evoke very decided expressions of opinion both favorable and unfavorable to its usefulness. Be that as it may, we are of the opinion that the ophthalmometer is one of the most valuable instruments that we have in refractive work and we hope to defend our position in the succeeding paragraphs. Incidentally, let it be stated at once that the findings by ophthalmometry and the ultimate prescription given the patient, in so far as the astigmatic correction is concerned, may not be in agreement. There are various reasons why this may occur. Furthermore, differences in various sets of findings by different methods (e. g. ophthalmometry, retinoscopy—both static and dynamic—and subjective tests—both with and without cycloplegics) should lead to a careful, analytical study of the case in hand from all standpoints. Variations in data by different methods ought always to furnish us with the information needed for final analysis of the case and the expression of our judgment as to the corrections to be offered or the treatment to be accorded. Let us, then, briefly state the following facts germane to the topic under discussion: (1) The ophthalmometer measures anterior corneal curvatures and astigmatic conditions only; hence these findings may be ultimately modified by posterior corneal conditions or by lenticular conditions involving regular or irregular astigmatism. (2) The subjective findings and corrections are obtained with lenses inserted somewhere near the region of the anterior focus of the eye: the effectivity of all lenticular corrections varies with the distances from the eye at which they are placed: hence ophthalmometric findings, on the one hand, and subjective and retinoscopic data on the other hand, may not apparently agree, whereas they may be in very good accord when proper allowance is made for the conditions which have

*OPHTHALMOMETRY AND ITS APPLICATION TO OCULAR REFRACTION AND EYE EXAMINATIONS, by Charles Sheard, Ph. D., Physiological Opticist, The American Optical Company, Editor of The American Journal of Physiological Optics et al.

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just been cited. (3) The ophthalmometer does accurately measure the curvatures in various meridians of the anterior corneal portion of the eyeball, hence affords some evidence as to whether or not the myopia or hyperopia subsequently disclosed by other tests is due, possibly, to axial or refractive conditions. (4) It furnishes a ready means of discovering irregularities of the cornea, which cause irregular astigmatism and generally produce reductions in the visual acuities.

THE OPHTHALMOMETER.

The first instrument was devised by von Helmholtz, who published a description in 1854. In the 80's Javal and Schiötz improved the instrument and gave it a semblance of the form it has today. Thus far ophthalmometers measuring corneal curvatures only have been perfected. Claims have been made as to the invention of instruments measuring lenticular condi-

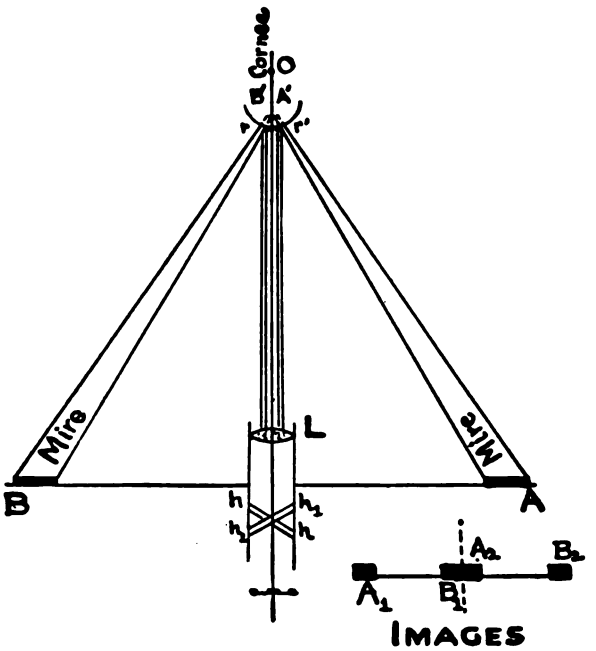

Figure 1. Diagram illustrating the essential principles underlying the construction and use of the ophthalmometer. The four images as produced by the doubling device are shown in an enlarged form at the lower right-hand corner.

tions, but none have, to our knowledge, been sufficiently perfected to warrant their general use in office practice. It is obvious that if the prisms in the telescope of the ophthalmometer are made movable, so that they can be shoved to and from the eye, we should have a scheme which, theoretically at least, should enable us to examine the cornea and the anterior and posterior surfaces of the lens. Special mires would be needed in order to give sufficient illumination and clarity of images. Such an instrument ought, if perfected, to aid in the settlement of many points of scientific interest; such, for example, as the mechanism of accommodation, the question of accommodative astigmatism, et al.

The fundamental parts of the ophthalmometer are the telescope, which carries the objective and an eye lens, a double refracting prism and a set of mires. In some instruments the overlapping or separation of images of the mires as seen through the telescope, is controlled by a movement of the mires through the rotation of a worm device whereby the mires are moved along an arc; in another type of instrument the mires are stationary but the positions of the reflected images of the mires, as seen by the operator, are varied by changes in the position of the prisms. These prisms are fitted into a special tube and carried back and forth by a rack and pinion device. In certain instruments the so-called "primary" and "secondary" positions can be readily turned from one to the other respectively by a simple rotation of the prisms. One form of instrument, not as successfully developed as we judge it can and ought to be, gives both primary and secondary findings in the field simultaneously.

The birefracting prism is of quartz and is so cut with respect to its optic axes as to give double images. This prism is, in reality, composed of two prisms with the apices in opposite directions, so placed as to cause the deviation to take place from each side. Since each prism produces a certain degree of deviation, twice the amount of separation is secured and at the same time the doubled images can be kept nearer the center of the field. The prisms are so mounted that their plane of doubling is in exact line with the plane of the graduated arc.

The telescope should be equipped with combinations of achromatic lenses. This is, in general, approximately the case, but we find in practice that the reflected images of the mires as seen in the field of vision under the magnification of the ocular of the telescope are often accompanied with colored fringes and indistinct edges which interfere with the determination of the exact coincidence of the mires in corneal examinations. These slight color fringes are due, without doubt, to diffraction effects which are produced by the texture of the cornea and which may, for example, cause the general character of the light reflected from the cornea as seen in the telescope to be bluish or reddish; they may, as their second source, be due to the dispersive effects of the prism system producing the doubled images; or, again, to lack of complete achromatism of the telescopic lens systems.

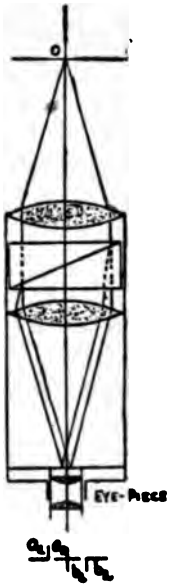

Figure 2. Detailed diagram of the objective, prism system, and ocular of the telescope of the ophthalmometer.

This clearness and sharpness of the edges of the mires and the freedom from colored edges in the region of contact of reflected images may be acquired, so E. LeRoy Ryer says, through the use of a red screen over one mire and a green

screen over the other mire, these screens having as nearly as possible complementary colors. It is desirable, however, to have access to white mires under other circumstances; hence both purposes may be accomplished by obtaining red and green colored celluloid pieces which may be slipped in between the glass plates of the mires and the mires proper. These may be inserted or removed in a moment's time. The writer has tried this scheme and found that it is excellent in some cases. For his own part, however, he has to state that, with oppositely colored mires, the phenomenon of different foci for different colors (i. e., stereoscopic vision for colors) occurs, so that the mire with the red screen is not sharply seen when the green one is. But the region of overlapping and that of "just in contact" are generally sharply defined. The effects due to a set of white mires and a set consisting of a red and a green one may be simultaneously obtained and the contrast noted by inserting the colored celluloid strips in such a way as to cover only half of each mire respectively. We note, in passing, that one of the American companies manufacturing ophthalmometers has for some years stated in its descriptive literature that the mires may be of any color desired, one red and the other green and so on, or both may be of white. It is their recommendation, however, that the mires be white as a general rule.

SOME PRACTICAL POINTS IN THE MANIPULATION AND USE OF THE OPHTHALMOMETER.

From the conversations we have had with many practitioners and from the questions asked or criticisms raised, we judge that many men do not thoroughly understand the niceties of manipulation of an ophthalmometer. Hence it is desirable that attention be called to these points.

1. The eye-piece. The examiner should first of all adjust the telescope by looking through it and turning the eye-piece (the end nearest the eye) until the cross-hairs are in perfect focus. This differs for individual operators, hence the reason for the adjustment. Likewise, these cross-hairs are easily gotten out of focus in the course of the use of the instrument. If these cross-hairs are not in proper focus, the images re-

flected from the cornea cannot be brought into correct focus, hence cannot be made as clearly and sharply defined as they should be. This adjustment of the eye-piece of the telescope is a frequent omission on the part of many practitioners. It should be stated, in passing, that some makes of instruments do not have such a device; this adjustment would not then be called for. .

2. The patient should be comfortably seated and the instrument placed upon an adjustable table or stand in order that a comfortable and uncramped position of the head and body of the patient may be assumed. Also, the operator should give some heed to his own comfort and efficiency in his work.

3. The forehead of the patient should be pressed against the top of the head-piece and, when in readiness for observations, the patient should be instructed to keep the head immobile.

4. The patient should be instructed to look at the end of the telescope. If necessary a small white fixation object may be provided and attached very close to the mouth of the telescope.

5. The line of sight of the eye and telescope may be approximated initially by observing the relative heights of the eye and telescopic tube through the slits or apertures provided in the metal screen to which is attached the arc carrying the mires, and a little above or to the side of the telescope. Very little further adjustment should be called for in this respect since the images from the cornea should be readily obtained and seen by the observer upon swinging the telescope around in line with the eye under test and by adjusting the telescope back and forth on the rack and pinion device provided for the purpose of focusing the images of the mires.

6. The images of the mires reflected from the cornea are to be focused so that they are the clearest and sharpest possible by a movement of the telescope only, without touching the eye-piece if such is present and in adjustment. Because of backlash it is advisable to always finally focus, whether in the primary or secondary positions, from the same direction; i. e., always finally focusing from a movement of the telescope for-

ward or vice versa. This point should always be heeded when comparing the results or data on the same cornea obtained by different makes and styles of instrument.

Figure 3. The corneal reflections as obtained with one form of modern ophthalmometer.

Figure 4. The corneal reflections as obtained with another type of modern ophthalmometer.

7. The patient's head should be in such a position that the eyes are horizontal, because if the head were tilted and one eye were higher than the other, the apparent location of the principal meridians would not be true, but might be off as much as ten to fifteen degrees from their correct positions. This requirement is readily fulfilled as follows: After having focused upon one eye and so arranged affairs that the two inner reflections from the right eye, for example, are practically centered with respect to the intersection of the cross-hairs, then immediately swing across to the left eye and if the head is in good adjustment from the standpoint just mentioned a similar condition will exist with respect to the location of the two inner images reflected from this eye with respect to the cross-hairs. In this manipulation the eye-cover should be swung to the median position so that both eyes may be kept uncovered.

8. The corneal reflections of the two mires are doubled by the bi-refringent prisms, and of the four images seen in the field the two inner ones only (which should ordinarily, with the dial pointer set at about the 45 diopter point, be close together or possibly overlap) being regarded. These images are then made to fall upon the point of intersection of the cross-hairs in the eye-piece by a manipulation of the telescope through a movement of the same up or down and by swinging

it upon its vertical axis. When this adjustment is obtained the telescope should be clamped so that it will not move from its position while various observations are being made.

9. The mires, (or prisms in the case of stationary mires), are moved along the arc by means of the milled head or worm-device on the back of the large dial, until the two middle images are just in contact at their edges. The telescope is then rotated, by grasping each end of the arc carrying the mires and turning with a circular motion, until the bisecting lines through each of the mires form a continuous line and the positions of the mires on the arc are readjusted, if necessary, for contact. This locates for us one principal meridian. (It is absolutely useless and valueless to employ the terms primary and secondary meridians in the sense in which they are often used; all the two words connotate is first and second positions of alignment).

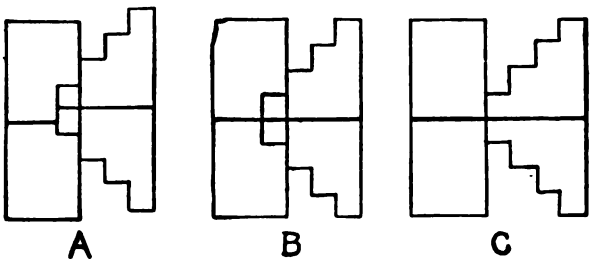

Figure 5. Corneal reflections of the mires. (A) Images overlapping and off a principal meridian. (B) Images overlapping but in a principal meridian. (C) Images in alignment and in contact in the horizontal meridian.

10. If the cornea is spherical, the central images will remain in contact as the arc, which carries the mires, is rotated about the horizontal line or axis of the telescope. If there is corneal astigmatism, the distance between the images will vary as the arc is rotated into various meridians on account of the variation of curvature or the toric form of an astigmatic surface. Furthermore, the images will have a curious excentric sliding motion with respect to each other. The two principal meridians should, under normal conditions, be 90 degrees apart. To locate a principal meridian, therefore, we have only to

locate that direction in which the black central lines, or their equivalents, on the mires are continuous with each other as viewed through the telescope, since this occurs only when the meridian parallel to the plane of the mires is spherical.

11. Various instructions are given with different makes of instruments as to the method of setting the pointers attached to the dial or the manipulations of the drum or dial arrangements for the adjustment of the prisms necessary for contact of the mires in different meridians and, through them, the determinations of the corneal astigmatic error if such exists. The writer recommends, for one or two reasons which will be considered directly, that the power in each principal meridian and the meridian measured be recorded for each eye. Thus, if the mires are in the horizontal (0-180 degree) meridian, we measure the power in that meridian. This is mathematically and physically equal to the power of a cylinder of like power to that determined by the ophthalmometer with the axis of the cylinder representing this power at right angles to the meridian measured. For instance, if the mires are in contact in the 90th meridian, (i. e., with the central lines continuous in the vertical direction) we are measuring the corneal power in the vertical meridian; let us assume this to be 45 diopters. We should, therefore, make our record as showing the equivalent corneal power of the eye in the 90th meridian as 45 D. cyl. ax. 180. In practice, therefore, we simply record both the power and the meridian measured somewhat as illustrated in the following:

Ophthalmometric Data.

Eye	Power	Meridian Measured
Right	45 D.	90
	48 D.	180
Left	43 D.	100
	42 D.	10

These data may be conveniently recorded, as shown in the accompanying diagram, by the use of a circle and a cross drawn in the position of the principal meridians, each meridian measured being marked with the value of the power possessed.

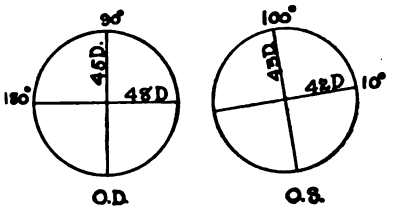

Figure 6. Diagram illustrative of a simple method of recording the principal meridians and their powers in a pair of eyes.

In the case of the right eye we have recorded an assumed corneal astigmatism of 3 diopters. There is no direct evidence, per se, that a minus or plus cylindrical correction will be required in the prescription, since that phase of the data must rest upon whether or not the eye has simple hyperopic astigmatism, simple myopic astigmatism or compound or mixed astigmatism. Such data must come from retinoscopic and subjective tests. Neither, again, have we any reason to believe that the ophthalmometrically determined astigmatism will agree in amount or exact axis with that finally fixed upon and judged to be the correct astigmatic finding. We shall discuss this matter thoroughly in other paragraphs. However, we do have a condition of corneal astigmatism against the rule, as it is known, since the vertical meridian has less power than the horizontal meridian. The difference in corneal curvatures in the illustration chosen is represented by the equivalent of a 3 D. cyl. ax. 180 placed in contact with the cornea. This would add three diopters of power to the vertical meridian and hence make both powers equal to 48 diopters. Or again, a —3 D. cyl. ax. 90 might be thought of as being in contact with the cornea; this would take away three diopters of power from the horizontal meridian and hence make both powers equal to 45 diopters. This would mean, in other words, that we would have made through the addition of the cylinder a spherical refracting surface of the cornea. If there were no other sources of astigmatic error in this eye, which would either add to or subtract from the total corneal astigmatism, and if account need not be taken of the effectivit[illegible] lenses

at appreciable distances from the eye, we should expect to find by retinoscopic methods an amount of astigmatism approximating that just specified.

In the case of the data given with reference to the left eye, however, we have a corneal astigmatism with the rule, in which the vertical meridianal power is greater than the horizontal, thereby demanding in the illustration chosen a one diopter cylinder to make both meridians of equal power. This may be accomplished, (from the standpoint of the ophthalmometric findings but not, it is to be remembered, necessarily in exact agreement with the amount of astigmatism determined by other methods) by either a 1 D. cyl. ax. 100, which would add power to the horizontal meridian and therefore make both meridians of 43 D. power or by the use of a —1 D. cyl. ax. 10, which would take away power from the vertical meridian and cause both meridians to have equal powers of 42 D.

We shall have occasion to discuss some very vital points with respect to the significance of these corneal findings in paragraphs devoted to a discussion of theoretical and practical interpretations of ophthalmometric findings.

In closing these remarks on the manipulation and use of the ophthalmometer we desire to say that we have referred to the classic form of instrument with movable mires. Another excellent make of instrument has stationary mires with the adjustment of images made through an arrangement controlling the prisms. In the statements we have made it is, therefore, necessary to speak only of the fact that adjustment of images by the prism movement device is synonymous with movements of the mires along the arc.

SOME SIMPLE THEORETICAL CONSIDERATIONS.

For all practical purposes the anterior surface of the normal cornea may be considered as a convex mirror. We know that the sizes of the images reflected in plane mirrors are of the same dimensions as those of the objects. With convex mirrors the image is always apparently behind the mirror and much smaller than the object. The smaller the radius of curvature or the greater the curvature of the convex surface the

smaller will be the size of the image. Hence, if the convex mirror should be more curved in one meridian than in another, the reflection of a circular object would no longer be round but would be oval, with the longer axis parallel to the meridian of least curvature.

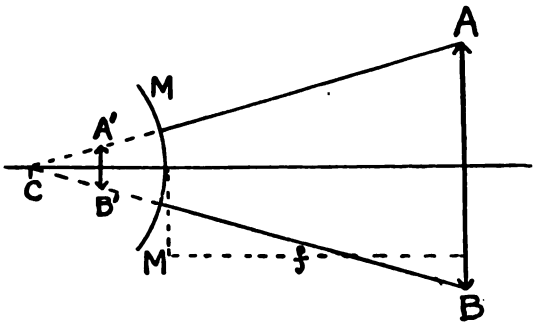

Figure 7. Illustrating the fundamental physical priciples of reflection from convex mirrors or from the cornea.

The accompanying diagram shows the fundamental principles of the reflection of images by convex mirrors or the convex cornea. M M represents the cornea and A B is to be considered as a single mire. The distance M A is large (say a foot) as compared with the radius of curvature of the cornea which is, on the average, about 7.8 millimeters. The image of A B, i. e. A′ B′, will be formed back of the mirror and practically at its focal point, F = r/2.

The simple ophthalmometric formula is

$$r = \frac{2fI}{O}$$

in which r is the radius of curvature, f is the object distance, O the size of the object and I the size of the image.

This is the equation which must be satisfied in the construction of the ophthalmometer and from which it may be calculated (see Sheard's Physiological Optics, pages 51-53) that the strength of the doubling prism used in modern ophthalmometers is so arranged as to give a displacement of exactly 3 millimeters.

The ophthalmometer is used to find the anterior focal power of the cornea. The dial or disc is usually marked in both

diopters and in millimeters radius of curvature. So many errors have been seen by the writer in printed statements having to do with the calculations of these dioptral powers and radii that he may be pardoned a brief reference to the correct equation and its use. The anterior corneal focal power is represented by

$$D_c = \frac{1000\,(n - I)}{r}$$

where r is the radius of curvature in millimeters and n the index of the cornea. It is quite commonly stated that the index of the cornea is the same as that of the aqueous or water, namely 1.333. Such is not true, for the cornea has an index commonly assigned as 1.3375. If this number is used in the above relation we find that a radius of 7.5 mms. corresponds to a power of 45D. To anyone who will take the trouble to check out the accuracy of the markings in diopters power and in millimeters radius of curvature by the foregoing equation the following may be of service:

Power in diopters.....	40	41	42	43	44	45	46	47	48	49
Radius in millimeters.....	8.44	8.23	8.04	7.85	7.67	7.50	7.34	7.18	7.03	6.89

POSSIBLE VALUE OF OPHTHALMOMETRIC CURVATURES IN HYPEROPIA AND MYOPIA.

It is probable that the ophthalmometric measurements of curvature do lend information of value in many cases of hyperopia and myopia. Calculations show that an increase or decrease of one millimeter in length of an eyeball along the axis corresponds to two and one-half to three diopters of refractive change. It is probable that variations in the lengths of eyes through the ocular axes are greater than are the variations in corneal curvatures. But variations in the curvature of the cornea affect the refraction to a greater extent than do variations in length. For a variation of one millimeter in the anterior corneal radius of curvature corresponds to about six diopters. Hence, high or low corneal curvatures may be important etiological factors in myopia and hyperopia or in

tendencies thereto. If, then, the eye is, for example, highly hyperopic (let us say 6D.) and the corneal measurements should indicate curvatures as low as 40 to 41 diopters we should be justified, we believe, in including that the hyperopia was of a curvature type rather than being axial, or possibly lenticular in nature. The possibilities for vision, when corrected, might be expected, other features not proving the same to be impossible, to be raised to something approximating the normal standard. But if an amblyopic eye, of 6 diopters for example, were under examination and the curvatures of the cornea were about normal and of practically the same values as those of the other eye, we should be compelled to look elsewhere for the seat of the hyperopia and of the amblyopia. The values of the visual acuity, before and after correction, would then depend largely upon the history of the case and the previous treatment.

In myopia there are two important points which should be settled: the measurement of the radius of curvature of the cornea and the examination of the fundus. Let us say that the average curvature of the cornea is 7.65 mm. as a very fair estimate. If the radius of curvature is less than this, it indicates a cornea with a sharper curvature and hence greater refractive power; whereas, if the radius be longer the cornea is flatter and less powerful refractively. In general, then, a short radius of curvature in myopia indicates that the case is of a benign refractive character in which the rays are brought to a focus in front of the retina by virtue of the excessive refractive power of the cornea. If, however, a reasonable amount of myopia exists (i. e. two diopters or more) and the radius of the cornea is large or even normal, there is then a fair indication that the myopia present must be due to the displacement of the retinal tissues backward. This would indicate the progressive axial type of myopia. The examination of the fundus by means of the ophthalmoscope is of considerable value here. For, if there are no changes present in the fundus of a person with a short corneal radius it is perfectly safe to say that the case is a non-progressive [illegible] absence of fundus changes is not so conclusi[illegible] corneas,

since the myopia is evidently axial and not refractive and changes are likely to develop later. If, perchance, those changes are present which indicate an inflammatory softening of the structures at the posterior pole, then the diagnosis of progressive myopia can be made with considerable certainty.

IRREGULAR ASTIGMATISM.

Before the days of the modern ophthalmometer and other methods of diagnosis no class of refractive cases was more troublesome or difficult to handle than those with irregular curvature of the cornea. In the ophthalmometer, the images of the mires are of value in detecting irregular astigmatism,

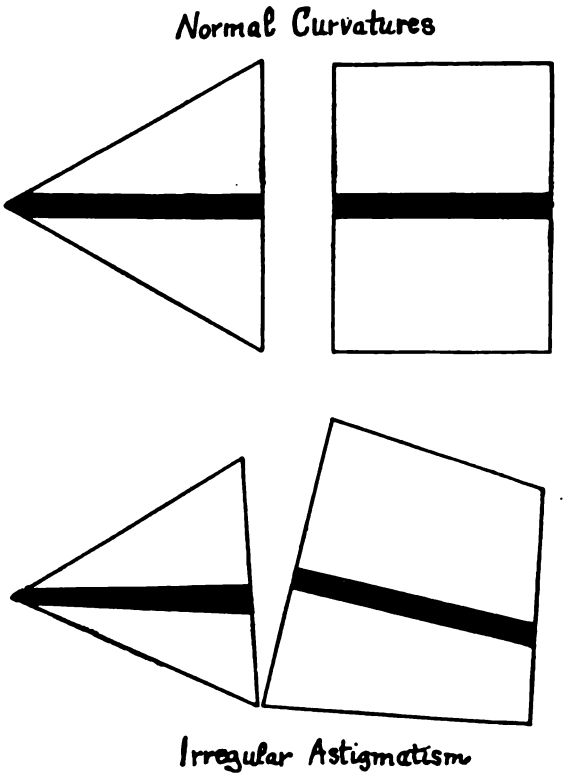

Figure 10. Upper diagram shows the normal reflections of mires in a principal meridian. The lower diagram shows the distortion in a case of irregular astigmatism.

for they show distortion of the corneal image and the irregularity of the outlines of the mires when corneal irregularities exist. Such irregular astigmatism is also shown when there is no position of the mires in which the corneal reflections can be made to form one continuous line. This condition of affairs is roughly diagrammed in the figure given below, in which the upper illustration shows the normal condition of affairs while the lower diagram attempts to represent the distortion with lack of continuity of the central lines of the mires in irregular astigmatism. The best procedure, then, is to find the position of nearest approach to normal corneal reflections in two meridians as nearly at right angles to each other as possible. Or, to state it another way, regular astigmatism may be present in addition to the irregular form: there are then, in general, two positions at which these lines become more nearly continuous and straight and afford more nearly normal contact than elsewhere, thus indicating the meridians of the regular astigmatism.

The ophthalmometric examination is so delicate in the distortion test through the images of the mires that the smallest irregularities of the corneal surface may be detected. Following such an examination, there should be made a close inspection of the surface of the cornea by oblique illumination and an examination for minute opacities, facets and pits. Likewise, the ophthalmoscopic examination may afford evidence of the

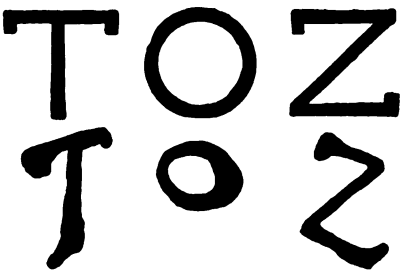

Figure 11. The upper row of letters is a reproduction of a well-known set of letters on a test-card; the lower set represents these letters as diagrammed for us by the patient in a case of irregular astigmatism.

presence of such irregularities, for the writer has had cases in which, when viewed at the proper angle such as to include the irregularity, a doubleness of optic disc, etc. was visible. Subjectively the condition may often be detected by the distortion and grotesque forms which the larger letters in our test charts assume. One or two patients have sketched these for us and we are appending one set taken from our history cards. The first row of letters represents normal conditions; the second set as seen by this patient.

In passing, let it be said that we have found that the use of the stenopaic slit in these cases of irregular astigmatism, with the determination of the meridians of best and poorest vision and their independent correction, to be ultimately combined into a sphere-cylinder combination, has been of great service. And the ophthalmometer aided greatly in the location of these two meridians.

To illustrate the points we have been discussing we are citing two cases. It should be remarked that many, if not most, of these conditions of irregular astigmatism are the sequelae of various types of ulcers.

KERATOCONUS.

Keratoconus is a non-inflammatory conical protrusion of the center of the cornea and is due to a thinning of this membrane whereby it is unable to resist the normal intra-ocular pressure. Conical cornea causes myopia and astigmatism and seriously interferes with vision even after the best possible corrections with lenses. The most valuable objective test is that with the ophthalmometer. The retinoscopic procedures may be of value. The subjective tests with the trial lenses are often facilitated by the employment of the stenopaic slit. In keratoconus there is always more or less irregular astigmatism. The ophthalmometer is not generally capable of locating the axes with exactness or of measuring their powers, but it does afford a method of close approximation. The ophthalmometer and the Placido's disc enable one to select the area in or near the visual area which is best suited for visual purposes. In the high amounts of astigmatism that commonly occur in

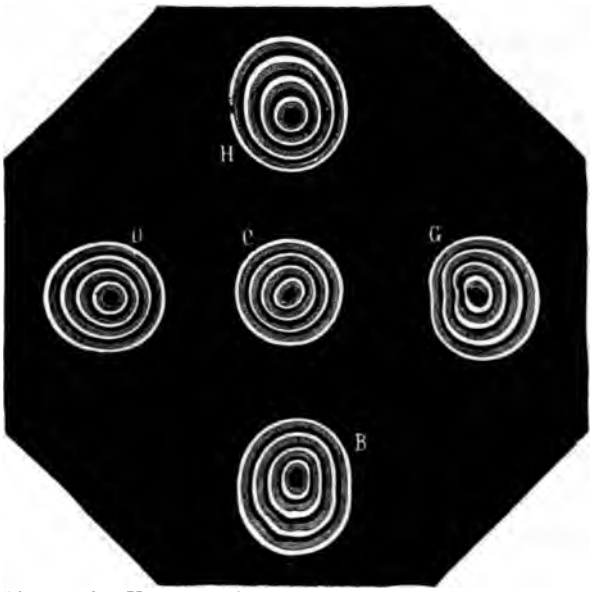

Figure 12. Keratoscopic figures of a cornea presenting a considerable astigmatism at the central part. (After Javal.)

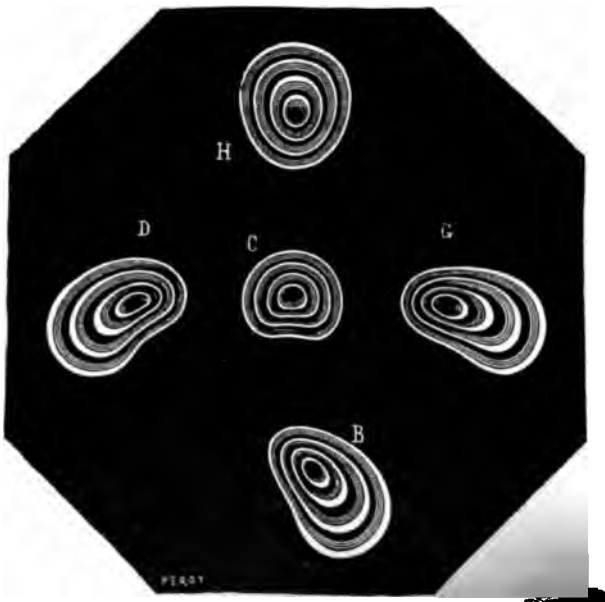

Figure 13. Images from the Placido's di[illegible] keratoconus. (After Javal.)

conical cornea it is necessary to add an extra prism to the ophthalmometer. This decreases the sizes of the images of the mires one-half, but enables the operator to measure much higher degrees of astigmatism.

While the power of the normal cornea varies between 40 and 48 diopters, higher values are found in cases of conical cornea. Instances of 60 to 80 diopters are occasionally found: in fact, Cordiale found a case in which the curvature was about 100 diopters, corresponding to a radius of 3.4 mms. Various ophthalmometric examinations in such cases, made by Cordiale, show that the dioptric powers of the cornea, at points one or two millimeters to the nasal or temporal side of the visual line, change as much as 20 or more diopters, whereas in the normal cornea there is practically a uniformity of curvatures over this same region..

ADVANTAGES OF OPHTHALMOMETKIC MEASUREMENTS.

As mentioned in other sections of this volume, the ophthalmometer is designed to measure the radius of curvature of the cornea and to thereby determine its refracting power. The facts which are obtainable through the making of these measurements include:

(1) Whether the corneal curvatures are the same in all meridians or not: if there is no difference, then there is no corneal astigmatism.

(2) Whether the radius of curvature is shorter or longer than the average. This is of value even though no corneal astigmatism is found, for the reason that a difference of one millimeter in the radius of curvature of a cornea corresponds practically to six diopters of refracting power. It is commonly found that an eye having a cornea with a radius of one-half millimeter or more shorter than the average is myopic: in turn, one with a radius of curvature one-half millimeter or more longer than the average is hyperopic. Hence, the ophthalmometric measurements may be of service in indicating refractive, curvature or axial hyperopia of myopia.

(3) Whether the cornea has a toroidal curve; if so, corneal astigmatism is present. The principal meridians and their

powers may be located accurately. The operator will not be able to determine whether a plus or minus cylinder should be accepted by the patient, but he will be able to determine where to place the axis of the plus or minus cylinder indicated, should either be eventually accepted, in so far as corneal conditions are concerned. There are possible exceptions to this last statement, especially in cases of cyclophoria at close points when there is an absence of cyclophoria at distance. Of course, the reader is not to imply from the foregoing statements that the ophthalmometric findings as to axis are infallible: they simply show corneal conditions.

(4) We may determine whether irregular astigmatism or keratoconus is present or not and to what extent. Any asymmetry of this character will be readily detected, for the images of the mires will be distorted. Frequently the images of the mires lose all resemblance to the mires themselves.

(5) We may determine whether the corneas of the two eyes are similar or dissimilar and whether the corneal astigmatism, if present, is symmetrical or unsymmetrical. To illustrate: if the meridian of greatest refraction is at 90 degrees (or 180 degrees) in both eyes, the patient then sees vertical or horizontal lines sharply (dependent upon the error) without torting the eyes. If the meridians are 90 degrees and 70 degrees respectively, the patient will be unable to see the same lines distinctly with both eyes unless he tilts his head some 10 degrees in order to bring the two principal meridians into some thing like symmetrical positions, or else the oblique muscles will have to tort the eyes in the interest of clear binocular single vision. It is likewise true that the condition of slightly blurred yet equal or similar images upon the maculae of both eyes is less destructive to good vision than the condition of a blurred image upon the macula of one eye and a sharp image upon the macula of the other. Great care is necessary to see that the cylinders are correctly placed in order that no tilting of the head or torting of the eyes (cyclophoria) shall be induced for the purpose of obtaining similar images upon the two maculae. Hence, we particularly desire that the eye

remain in its position of rest. If the axes of the cylinders are incorrectly placed, asymmetrical meridians may be produced, causing the eyes of the patient to be torted or the head to be tilted, thereby producing more or less discomfort.

It is often of the greatest value to note the expressions of opinion of scientific men upon various phases of the work in which they are interested. Opinions from as widely separated geographical sources are equally to be desired: we may, therefore, be pardoned the insertion of a lengthy quotation from an address on "Errors of Refraction" (British Journal of Ophthalmology, Vol. II, June, 1918) by Lieut.-Colonel R. H. Elliot of London, England. He says: "The uses of an astigmometer, as they appear to me, are as follows: (1) The instrument will often give the exact axis of the astigmatism. (2) When the axes of greatest and least astigmatism are not at right angles with each other, it will point out the discrepancy and give both readings. (3) Though it only measures the corneal astigmatism, and though a correction has almost invariably to be made to its readings, it furnishes valuable data in a large number of cases. (4) In asthenopic patients, with low astigmatism against the rule, it will point out the defect unerringly, and indicate the need for a cycloplegic retinoscopy, even though the vision is fully normal. (5) In cases of high hyperopic and myopic astigmatism, which present great difficulties for satisfactory retinoscopy, its indications prove more than valuable in a large number of instances. (6) In cases with deep medial opacities, sufficiently dense to make retinoscopy unsatisfactory, the correction of the corneal astigmatism, made by the aid of the astigmometer, may prove of much use. (7) In the routine examination of presbyopes, before prescribing a reading correction, astigmometry shortens the examination and adds precision to it. (8) In children, restless patients, and imbeciles, it sometimes proves a valuable auxiliary to, or even substitute for, retinoscopy. (9) As a means of ascertaining whether any surgical procedure or corneal affection alters the corneal astigmatism, it is unrivalled. Incidentally, its use in this connection sometimes

furnishes information of great interest. May I cite one example? The corneal astigmatism, found after cataract extraction as shown by the astigmometer, is markedly in excess of the total astigmatism present. There is, therefore, a compensatory factor in action and this, I think, is to be sought at the anterior surface of the vitreous. I am not aware that this observation has ever been put on record, but any of you can confirm it for yourselves. (10) It will unerringly and immediately show the presence of slight nebulae of the cornea, irregular corneal astigmatism, disparities between the curvature of one and another part of the cornea, such as produce scissor movements in retinoscopy, and the existence of conical cornea."

Furthermore, there are the reports of John Rowan (British Medical Journal, 1912) in which the astigmatism in a thousand eyes was measured, first by the ophthalmometer of Javal and Schiötz and then by retinoscopy, with atropin or homotropin as a cycloplegic. The results of his measurements show that, out of the one thousand eyes examined, the total astigmatism and the corneal astigmatism were in agreement in nearly fifty per cent of the cases. This is surely an interesting and valuable conclusion and comes as a brisk rejoinder to those who minimize the value of the ophthalmometer in ocular refraction to the point of stating that it is of no value whatever.

A DISCUSSION OF THE RELATIONS BETWEEN CORNEAL AND TOTAL ASTIGMATISM.

Quite a difference is often found between the ophthalmometric and subjective measurements. This was first pointed out by Donders and later by Knapp who attributed—with a fair degree of accuracy in many cases—this difference to an astigmatism of the crystalline lens which would act in a contrary direction to that of the corneal astigmatism. Javal, Pflüger, Tscherning and others have investigated the relations between corneal and total subjective astigmatism.

The rules of Javal, commonly accepted by most investigators and refractionists as being a first order approximation to the truth and hence of much value, are:

(1) If there is no ophthalmometric astigmatism, we generally find a slight subjective astigmatism against the rule. This condition would, of course, call for corrections involving plus cylinders at or in the vicinity of 180 degrees or minus cylinders at or in the vicinity of 90 degrees.

(2) If the ophthalmometric astigmatism is against the rule, the subjective astigmatism is usually against the rule and of a greater amount.

(3) If the ophthalmometric astigmatism is with the rule and of a value intermediate between one and three diopters, the subjective astigmatism generally differs only slightly from it.

(4) If the ophthalmometer gives an astigmatism with the rule and greater than three diopters, the subjective astigmatism is also with the rule and frequently greater.

Javal expressed the difference between the subjective astigmatism (As_s) and the ophthalmometric astigmatism (As_c) by the empirical rule or formula that

$$As_s = k + p.As_c$$

in which k and p are two constants, k being approximately 0.5D against the rule and p having a value of 1.25, hence a multiplying factor a little greater than unity. We can physically and physiologically account for the significance and value of the term k but we know of no investigator or writer who has satisfactorily explained why the factor p should be greater than unity. Since k has a value of 0.5D. against the rule, it is necessary to add it to the ophthalmometric finding in cases of astigmatism against the rule and to subtract it in cases of astigmatism with the rule.

The formula gives the following numerical values which are found to check reasonably well in ordinary, everyday practice:

Ophthalmometric Astigmatism	Against the Rule			With the Rule					
Subjective Astigmatism	2	1	0	1	2	3	4	5	6
	3	1.75	0.5	0.75	2	3.25	4.5	5.75	7

Certain factors must be considered when discussing the reasons why ophthalmometric astigmatism and the total astig-

matism as found by other methods are often not in conformity with each other: (1) the positions of the lenses in front of the eyes and the influence of the distance of the correcting lens from the eye; (2) deformity of internal surfaces or astigmatism due to the forms of the internal ocular surfaces; (3) normal or abnormal lenticular astigmatism; (4) astigmatic accommodation; (5) astigmatism by incidence and crystalline lens obliquity; (6) spherical aberration and the astigmatism in the different zones of the cornea and (7) contraction of the recti muscles.

(1) The influence of the distance of the correcting lens from the eye. Years ago Javal and Pflüger carried out corrections of astigmia subjectively, the first named investigator using plus cylinders whereas the second used minus cylinders. The subjects were examined in common, and the ophthalmometric data afterward compared with the subjective astigmatic findings. It was found that Javal obtained higher corrections than Pflüger throughout the whole gamut of astigmatism tested. The astigmatism of the eye was, under their methods of testing, constant: hence the difference in their cylindrical corrections for various ophthalmometric determinations is due, in part at least, to the effectivity of plus and minus corrections situated at a certain distance from the eye. We must, therefore, take account of the change of effectivity of cylinders as they are placed in advance of the cornea and as they are convex or concave: hence, apparent changes in the astigmatism of the eye may arise from optical sources. To illustrate: Suppose there is found with the ophthalmometer 4D. of actual corneal astigmatism: there will then be theoretically required, if the eye is otherwise emmetropic and the cylinder is placed about 20 mm. from the principal plane of the cornea, either a cylindrical correction of +3.70D. or —4.35D., dependent upon the nature of the astigmatism. (Vide: American Encyclopedia of Ophthalmology, Vol. XIII, pages 9814-18 and 9873-76, and Sheard: Physiological Optics, pages 94-98 and 151-157.)

(2) Astigmatism due to the forms of the internal ocular surfaces. About seventy per cent of all corneas show an

astigmatism of from 0.5D. to 1D. at the anterior corneal surface. We know but little about the posterior surface but the experiments of Stadfeldt and of Tscherning show that the vertical meridian of the posterior surface of the cornea possesses a more pronounced curvature than the horizontal meridian, whether the condition in toto is one of astigmatism with or against the rule. Since the posterior surface is concave, this greater curvature in the vertical meridian will cause an astigmatism against the rule. It may well be that this is the cause of the small subjective astigmatism against the rule, generally found subjectively when the ophthalmometric findings show no anterior differences in various meridians.

Tscherning, Stadfeldt and Awerbach made measurements upon the crystalline lens, using an instrument known as the ophthalmophakometer. The anterior surface of the crystalline in all cases examined showed a direct, or with the rule, astigmatism while the posterior surface often exhibited the inverse, or against the rule, type. We are to judge in a general way from the results of their experiments that the crystalline surfaces are more spherical in form than the cornea.

(3) Lenticular astigmatism. Javal, Nordenson, Schiötz and others have shown that the lenticular astigmatism as a rule amounts to about half a diopter. This may be called the normal lenticular astigmatism, just as we have about the same amount of astigmatism normally present in the cornea. In general the two neutralize each other in the sense that they offset each other, producing the equivalent spherical error.

Dr. Davis (Essay on Refraction and Accommodation of the Eye: The American Encyclopedia of Ophthalmology, Vol. XIV, page 11164) writes: "The lenticular astigmatism, as a rule, amounts to about 0.50D. to 0.75D., as proved by abundant statistics, and it has been shown that, in actual practice, the corneal astigmatism is diminished or increased that amount, according as the astigmatism is with or against the rule. The most reasonable explanation to be given for the necessity of deducting 0.5D. to 0.75D. from the reading of the instrument

when the astigmatism is with the rule and adding a like amount when the astigmatism is against the rule is the assumption that in corneal astigmatism with the rule there is usually associated a lenticular astigmatism of 0.50 to 0.75D. in the same meridian, but of an opposite kind, thereby neutralizing that amount of corneal astigmatism. In astigmatism against the rule there is, on the other hand, a lenticular astigmatism of 0.50 to 0.75D. in the same meridian and of the same kind, thereby adding that amount to the corneal astigmatism. This can be explained in another way. In corneal astigmatism with the rule the lenticular astigmatism may be of the same kind but in a meridian at right angles to the corneal astigmatism; in which case, if the meridian at error in both the cornea and lens were myopic, a simple myopia of 0.50 to 0.75D. would be produced. . . . However, the first explanation is more likely to be the true one and, in fact, actual measurements (Donders) have shown it to be true; and the ophthalmophakometer confirms this view."

(4) Astigmatic accommodation. Dolrowolsky first expressed the idea that astigmatic persons could partly correct their defect through an irregular or non-uniform contraction of the ciliary muscle, thus producing a deformity of the crystalline lens in the opposite direction. Some experimenters and clinicians admit this possibility and others do not. There are a considerable number of physical facts against the acceptance of astigmatic accommodation. Still these and other facts do not bar its existence. It is entirely possible from anatomical standpoints, since it is possible that a part of the filaments which go to the ciliary muscle may be in a normal condition, while others may be partially paretic or insufficient or, again, over-active, thus producing irregular action on the zonula. And again, subjectively no astigmatism may be evidenced, the vision being 20/20 easily, while all objective tests show the presence of a decided astigmatism, indicating an astigmatic accommodation. Furthermore, we know from clinical experience that the correction of an objective astigmatic condition lessens discomfort and relieves ocular headaches in many cases although no improvement of the vision may result. (Vide,

astigmatism of from 0.5D. to 1D. at the anterior corneal surface. We know but little about the posterior surface but the experiments of Stadfeldt and of Tscherning show that the vertical meridian of the posterior surface of the cornea possesses a more pronounced curvature than the horizontal meridian, whether the condition in toto is one of astigmatism with or against the rule. Since the posterior surface is concave, this greater curvature in the vertical meridian will cause an astigmatism against the rule. It may well be that this is the cause of the small subjective astigmatism against the rule, generally found subjectively when the ophthalmometric findings show no anterior differences in various meridians.

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Dr. Davis (Essay on Refraction and Accommodation of the Eye: The American Encyclopedia of Ophthalmology, Vol. XIV, page 11164) writes: "The lenticular astigmatism, as a rule, amounts to about 0.50D. to 0.75D., as proved by abundant statistics, and it has been shown that, in actual practice, the corneal astigmatism is diminished or increased that amount, according as the astigmatism is with or against the rule. The most reasonable explanation to be given for the r
deducting 0.5D. to 0.75D. from the reading of th

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Howe: Muscles of the Eye, and Sheard: Physiological Optics, page 144.)

(5) Astigmatism by incidence and lens obliquity. The pupil of an eye is ordinarily centered with respect to the axis of the ocular system. The point of fixation is, however, upon the visual axis. The angle between the optical and visual axes is generally known as the angle alpha, usually of the order of about 5 degrees. Hence, even though the incident beam along the axis should be devoid of astigmatism, the beam along the visual axis will not be. By virtue of this angle alpha an "against the rule" astigmatism arises which is, on the average, about one-half to three-quarters of a diopter. The following table is self-explanatory upon this point:

	Angle Alpha (Degrees)				
	1	3	5	7	9
Corneal Astigmatism	0.02D.	0.13D.	0.35D.	0.66D.	1.11D.
Lenticular Astigmatism	0.01D.	0.05D.	0.14D.	0.26D.	0.44D.
Total Astigmatism (Diopters)	0.03D.	0.18D.	0.49D.	0.92D.	1.55D.

Another form of astigmatism due to incidence may be designated as astigmatism due to lens obliquity. For example, if the crystalline lens should be tilted about its horizontal axis, there would be produced thereby an astigmatism against the rule. A tilting of the crystalline lens in situ of 10 degrees would cause an astigmatism of about 0.5D. The Bowman muscle and not the ciliary is involved in the placing and in the holding in position of the crystalline lens. Savage (Ophthalmic Myology, 2d edition, pp. 637-38) discusses in a very entertaining manner his own condition of astigmatism, both from the ophthalmometric and subjective testings over a period of years, and attributes the differences in large measure to the lenticular astigmatism produced by a tilting of the crystalline lens.

(6) Spherical aberration. In quite high degrees of astigmatism the images of the mires are affected by spherical aberration. On this account there is recorded an excess of error. Leroy and Reid insist that a proper reduction in the astigma-

tism measured by the ophthalmometer must be made if it is to accord with that found on subjective examination.

(7) Contraction of the recti muscles. By voluntary action the recti muscles, in a few cases, alter the corneal astigmatism. Davies (Essay on Refraction and Accommodation of the Eye, American Encyclopedia of Ophthalmology, Vol. XIV, page 1168) reported in 1895 the case of a patient who had a corneal astigmatism with the rule of 0.5D. which could be, by voluntary action of the recti muscles, increased to 2D. in the right eye and to 1.5D. in the left eye. Under a cycloplegic he could still increase the astigmatism in the right eye to 1.5D. and in the left eye to 1D.

Ophthalmopathy. The pathology of the eye.

Ophthalmophthisis. Wasting of the eyeball.

Ophthalmoplegia. Paralysis of the muscles of the eye.

Ophthalmoptoma. Protrusion of the eyeballs.

Ophthalmorrhagia. Bleeding from the eyes.

Ophthalmorrhexis. Rupture of the eyeball.

Ophthalmoscope. An instrument devised by Helmholz for obtaining a view of the fundus of the eye. It consists, in its essential construction, of a concave mirror with a central peephole. By means of the mirror, light is thrown into the eye

Loring Ophthalmascope.

and on to the retina, and as the light emerges from the patient's eye the observer's eye is interposed in the path of the emergent rays by being placed behind the mirror at the peep-hole.

The modern ophthalmoscope is furnished with a self-illuminating electric bulb and battery, and fitted with a set of revolving lenses which can be wheeled, at pleasure, between the observer's eye and the patient's.

OPHTHALMOSCOPY.

Ophthalmoscopy, as its name implies, is an objective method of viewing the interior of the eye. Its principal—indeed, we might almost say its only practical use is for the detection of pathological conditions of the eye, which manifest themselves in altered appearances of the retina, choroid or optic disc, as seen through the ophthalmoscope. It can be utilized to determine the refraction of the eye, but its employment for this purpose is so difficult, and so susceptible of error, and there are so many and so much superior ways of estimating refraction, that nobody in his senses would, in these days, think of applying ophthalmoscopy to this form of work.

THE OPHTHALMOSCOPE.

The ophthalmoscope was designed by Helmholz in 1845. Under ordinary, unaided conditions it is impossible for one person to see another's retina, because when the two pupillary apertures (observer's and observed's) are directed toward each other, neither can be a source of light to the other, and no light can pass between them. It is for this reason that a person's pupil always appears black. The ophthalmoscope was designed to furnish means whereby light may be thrown, by reflection, into the subject's pupil and on to his retina, thus illumining the retinal ground, and the light emerging from the retina thus illumined may be intercepted by the observer's eye.

It is really a very simple instrument. It consists, essentially, of a small concave mirror, pierced through the center with a tiny sight-hole, and mounted on a stem handle. By placing a bright source of light just to one side of the patient's head,

on a level with the top of his ear, and holding the mirror so as to front his pupil, on a horizontal line with the pupillary center, the light can be thrown by the mirror straight into the pupil and on to the retina. If the observer's eye be now placed behind the mirror, thus held, so that he looks through the sight-hole, the light emerging from the patient's eye will pass directly through the sight-hole of the mirror and be intercepted by the observer's eye, and a view of the patient's retina thus obtained.

From the rather crude instrument originally devised by Helmholz and the modern ophthalmoscope is, of course, somewhat of a far cry. There have been no changes, however, in the essential principle. In the modern instrument, intended for use with an independent source of light, the small mirror is usually hinged upon a perpendicular swivel-pin, which enables it to be turned, laterally, to any required angle, so as to facilitate focussing the reflected light upon the patient's pupil. A still later and better development is the manufacture of an ophthalmoscope having its own source of light in the shape of a tiny high-power electric globe set at the top of the stem handle, immediately in front of the mirror at such an angle as to be horizontally reflected by the mirror. An arrangement for sliding the lamp up and down makes it further possible to change the focal relations of the lamp and the mirror, so as to vary the size and intensity of the illumination. This self-illuminating instrument does away with the trouble of focussing the disc of light upon the patient's pupil, and makes it possible to use the ophthalmoscope anywhere, in any position. The lamp is fed by a dry battery hidden in the handle.

Moreover, all ophthalmoscopes of modern make are furnished with a revolving battery of plus and minus lenses, set into a revolving disc behind the mirror, so that any desired lens power can be wheeled into place behind the sight-hole for observation purposes. This arrangement obviates the cumbersome necessity of placing lenses in a trial frame before the patient's eye.

DIRECT METHOD.

There are two methods of technique in the use of the ophthalmoscope, each having its special uses and advantages. The

direct method is as follows: Having thrown the light into the patient's pupil, we gradually approach, with the mirror, nearer and nearer to the patient's eye, until the mirror almost touches his face, and look directly at his retina. There are two or three conditions which must be observed in order to carry this out successfully. Both the patient's and the observer's eyes must be emmetropic—if not naturally so, then they must be rendered emmetropic by each wearing his proper correction; and both patient and observer must thoroughly relax their accommodation. Under these conditions, the patient's eye emits neutral waves, and the observer's eye is adapted to receive and focus neutral waves.

These conditions are not always easy to realize. It is especially difficult for the beginner in ophthalmoscopy to relax his accommodation when looking into a patient's eye. He is almost instinctively impelled to accommodate. Only by continued practice can he overcome this impulse. He must cultivate the habit of imagining that the retina he is looking at is away at the back of the patient's head. As soon as the conditions are met, the details of the eye-ground will spring into view.

By the direct method we obtain an enlarged, upright, virtual image of the fundus, with very clear detail, but we cannot see more than a portion of the field at a time, so that we must move the mirror from one focal plane to another, examining the various parts of the eye-ground successively. Its great advantage is the clear detail it affords us, and it is therefore the best method for examining conditions in which detailed pathology is of importance. The areas of the eye-ground are magnified, by this method, about 14 diameters.

INDIRECT METHOD.

By the indirect method we hold the ophthalmoscope about an arm's length from the patient's eye, throw the light into his pupil, and hold an objective convex lens of about 6 cm. focus, i. e., about 16 D. in front of his eye, between it and the mirror. The distance between the objective lens and the

mirror should now be adjusted—by moving either the lens or the mirror, or both, taking care to keep them horizontally aligned—until a focussed image of the patient's eye-ground comes into view. It is a much easier technique than by the direct method.

By the indirect method we get a real, inverted image of the eye-ground,—an aerial image made at the focus of the objective lens—enabling us to see practically all the fundus at once, but not in very great detail, as it is magnified only about 4 diameters. Its great advantages are the ease of its technique, and the perspective view it affords us of the fundus, showing us the relations of the various landmarks to each other—always bearing in mind, of course, that it is an inverted image, reversed in every meridian.

THE EYE-GROUND.

The combination of structures seen at the back of the eye by means of the ophthalmoscope goes by the name of the eye-ground, or fundus. It includes the blood-vessels of the retina (the retina itself, being transparent, is not seen in health), the vessels and pigment of the chorioid, the macula lutea, and the optic disc or nerve-head.

The normal color of the healthy fundus is a light reddish yellow, or orange, due to the admixture of yellow color from the choroid pigment and red from the blood vessels. It is impossible to write a description, or to present a colored plate, or even a series of colored plates, which will adequately cover all the variations in quality and range of shade that are included in the normal color of the eye-ground.

In blondes, the choroid pigment is exceedingly light; hence the fundus is correspondingly light, almost straw-colored, or perhaps a light vivid yellow. In brunettes, the pigment is dark brown; therefore the eye-ground is proportionately dark. Different nationalities exhibit different colors, chief among which are the Southern races, who have a characteristically deep, rich yellow tint, the Orientals, who have a peculiar stippled condition, easily mistaken for choroiditis, and the Negroes, whose funduses are almost dark grey in hue, because of the

interjection of their characteristic dark pigment. With all of these, and other, types of normal coloration the operator must make himself familiar.

Perhaps the commonest error made by beginners is to mistake an exceedingly pale fundus for anemia, or a rather deeply red one for retinitis. The truth is, neither anemia nor retinitis should be diagnosed upon the general coloration of the fundus, but upon the changes which take place in these conditions in the appearance of the vessels, which is described below.

Albinism. In some persons there is a congenital absence of pigment matter in the iris and choroid. (These two structures, it will be remembered, are parts of the same tunic.) In such cases the color of the fundus is a light pink, and the vessels of the choroid are very conspicuous. Other signs of albinism—milky skin, white hair, etc.—coexist.

THE MACULA.

About 1½ disc diameters to the temporal side of the fundus is a small area devoid of all vessels, in the center of which is a little spot of darker red than the rest of the eye-ground. This is the macula lutea, or yellow spot. Its actual size and color, like the color of the eye-ground, vary in different individuals. It is, of course, exceedingly sensitive to light, and the patient cannot stand the focussing of the ophthalmoscope upon this spot for more than a moment at a time.

THE NERVE HEAD, OR OPTIC DISC.

A little to the nasal side (by the indirect method, of course, to the opposite side) will be seen the head of the optic nerve, known as the optic disc. It appears as a small circular disc of considerably lighter color than the surrounding eye-ground—in health a yellowish-pink, with a soft lustrous texture. Its actual diameter is 1.5 mm., but under the magnification of direct ophthalmoscopy it appears to be about 2 cm. in diameter.

Normally the surface of the disc is flush with that of the fundus, and can be focussed simultaneously with the fundus. Under certain conditions, however, it is depressed below the level of the fundus, so that it cannot be simultaneously focussed. This condition is known as "cupped disc" and may

occur without the existence of any disease, in which case it is called "physiological cupped disc"; or it may be due to disease, either to optic atrophy or to glaucoma. It is highly important, therefore, that the practitioner be able to distinguish between a physiologic cupped disc and a pathologic one.

The principal indication that a cupped disc is physiologic is the absence of any other pathological conditions. The second is the fact that it is only partial, i. e., it involves only a portion of the disc, usually the central portion. Add to this a normal, healthy appearance of the disc itself, with the vessels riding smoothly and gradually over the edge, and the diagnosis of a physiological cupped disc is complete.

ABNORMALITIES OF THE DISC.

Depressions. Reference has already been made to the physiologic cupping, or excavation, of the disc. Total excavation is practically always pathologic, due either to optic atrophy or to glaucoma. As between these two, the distinction is often hard to make. In atrophy the cupping is shallow, as is shown by the absence of parallax motion on moving the ophthalmoscope slightly from side to side; the disc itself is dead white; and the vessels are indistinguishable. In glaucoma, the excavation is deep, with abrupt edges, and shows marked parallax motion; the disc is a gray pearl color; the veins are full and the arteries small.

Elevation. (Swollen disc.) This is just the opposite of the foregoing condition. The veins surrounding the disc are dark, full and tortuous, the arteries small. The nerve fibres are swollen and opaque, and the disc raised above the level of the fundus; its color is a reddish-gray, and its margin indistinct. This condition is known as optic neuritis, papillitis, or choked disc, and always indicates grave intra-cranial disease. Later on, the strangulation of the nerve-head, cutting off its nutriment, produces optic atrophy, and blindness.

Atrophy. In any form of atrophy the appearance of the disc is exceedingly white. Its exact color varies greatly, depending on many circumstances,—chalky, snowy, pearly, bluish, greenish, etc. But always it is exceedingly white, and has lost the soft, healthy lustre of the normal disc. Generally speaking,

atrophy is either primary, i. e., due to a disease of the optic nerve itself, or secondary, i. e., due to strangulation by optic neuritis. In the first type the color is a brilliant pearly white, the edges are sharp-cut and dark, the lamina cribrosa (see Anatomy) very prominent, and the vessels almost normal. In secondary atrophy the color is a dirty greyish-white, the edges indistinct, the lamina not conspicuous and the vessels are narrow and tortuous.

THE VESSELS.

The retinal vessels, arteries and veins, can be seen entering the eye around the margin of the optic disc, and distributing themselves in a radiating fashion,—principally in a north and south direction from the disc—over the eye-ground. The choroidal vessels can also be seen through the retina distributed over the choroid. The distinguishing points between the retinal and choroidal and retinal vessels are as follows:

Choroidal—	Retinal—
More numerous	Not so numerous
Larger size	Smaller size
Close together	Separated
Nearly parallel	Divergent toward periphery
Frequently anastomose	Do not anastomose
Same size along course	Diminish in size toward periphery
Veins and arteries same	Veins and arteries differ
Flat ribbon-like appearance	Cylindrical form

Considering the retinal vessels alone, we have to distinguish between the arteries and the veins. In health the differentiating points are as follows:

Arteries—	Veins—
Bright red	Dull red
Small in size	Large in size
Light streak down middle	Not very noticeable
Course fairly straight	Course rather sinuous
Do not pulsate	Frequently pulsate
Usually cross over veins	Usually cross under arteries

The eye is the only part of the body where the veins pulsate instead of the arteries—i. e., the interior of the eye. This is due to the incompressibility of the vitreous, which causes the pressure of the arteries, as the blood is pumped into them by

each heart-beat, to be instantly transmitted to the veins, forcing blood out of them; as soon as the heart-beat is over, and this pressure released, the blood comes back into the veins, thus giving them the appearance of pulsation.* The phenomenon can be made more noticeable by exercising gentle pressure on the side of the eyeball.

The pulsation of the vessels is reversed, i. e., the arteries pulsate instead of the veins, in any diseased conditions which raises intra-ocular tension, notably in glaucoma, of which it is one of the important symptoms.

ABNORMALITIES OF THE VESSELS.

Hyperemia. In all inflamed conditions of the retina or choroid the vessels, especially the veins, become enlarged and engorged. This state of affairs is most easily observed in the region of the disc, for here, as a rule, the vessels are not conspicuous, but when congested they thrust themselves upon the observer's notice being enlarged, flattened, and deepened in color. This is a much more dependable sign of inflammation than the general coloration of the fundus.

Special forms of retinitis and choroiditis will be described in another place.

Anemia. This is just the opposite condition of the foregoing. The arteries and veins are equally affected, hence they retain their relative sizes, but both arteries and veins are much smaller, often indistinguishable, and less red. There is a general pallor of fundus and disc, but the lustre of the latter is not lost.

Sclerosis. This condition pertains to the arteries alone. They become opaque, lose the light streak down their middle axes, and in advanced sclerosis become altogether white themselves, due to reflection of light from their opaque walls. The hardened arteries, pressing upon the veins where they cross them, obliterate them, so that the veins appear interrupted where the arteries cross them. There are areas of pallor over the fundus, where the nutriment is cut off by the obliteration of the vessels.

*This incompressibility of the vitreous and its transmission of pressure to the veins is similar in principle and mechanism to the incompressibility of water which gave the famous depth-bomb its effectiveness against the submarine—transmitting the pressure of its explosion instantly, through the incompressible water, to the submarine, causing its collapse inward.

Embolism. This is a plugging of the central retinal artery, or one of its branches, by a blood-clot floating in the blood-stream. It occurs suddenly. No blood gets into the retinal arteries supplied by the plugged vessel; hence the larger vessels are reduced to tiny white threads, and the smaller ones vanish altogether. There is an area of pallor around and adjacent to the disc, representing the portion of the fundus deprived of its blood supply. There is, of course, sudden and total blindness.

Thrombosis. This rare condition is essentially the same as embolism, except that the plugging of the artery takes place gradually, the final obliteration stretching over a day or two. The appearance of the fundus is the same.

Hemorrhage. In certain diseased conditions—usually those which raise the blood pressure and weaken the vessel walls, the retinal arteries, here and there, give way, and produce a hemorrhage on to the retina. Sometimes there is one large hemorrhage, but more often there are numerous small ones. The ophthalmoscope shows a cloudy retina, with variously shaped red splashes scattered over the ground—round, flame-shaped, linear, stellar, and irregular. After the hemorrhages have been absorbed, the red splashes are replaced by white spots.

These are the appearances seen in cases of retinitis due to profound systemic diseases, such as nephritis, diabetes, syphilis, malaria, etc.

Hyaloid Artery. Occasionally the hyaloid artery, which should disappear at birth, persists through life, in which case it appears under the ophthalmoscope as a dark gray-colored thread, attached to the disc, floating out toward the vitreous, and moving with rotation of the eye-ball. It is not a pathological condition, and should not be mistaken for one.

Cilio-Retinal Artery. In rare instances a medium-sized artery may be seen running from the temporal edge of the disc out toward the macula. This vessel is known as a cilio-retinal artery, because it is a branch of the ciliary circulation anastomosing with the retinal system. In retinal embolism the presence of this anastomosing artery is of great value, as it serves to keep the retinal area supplied with blood in spite of

the blocking of the central retinal artery, thus saving the patient from blindness.

ABNORMALITIES OF THE RETINA.

Most of the diseases of the retina are in reality diseases of the vessels supplying the retina, and have therefore already been described under Abnormalities of the Vessels. However, if a vascular disorder of the retina is sufficiently severe, or lasts long enough, it brings about actual pathologic changes in the retina itself. The principal changes to which the retina is subject are: (1) opacities, (2) exudations, (3) edema, (4) pigment changes, (5) detachment, and (6) atrophy.

All of these conditions, with the exception of pigment changes, are extremely difficult of recognition with the ophthalmoscope by any except an expert. Opacities are only recognizable by dint of our inability to focus certain areas of the fundus where the coat is opaque. Exudates and edemas exhibit a grayish color of the fundus, and the appearance of a gauzy veil, as though seen through a fog.

Pigment Degeneration. (Retinitis Pigmentosa.) This condition is more easily recognized. The pigmentation appears in masses or patches, deposited in the retina, following the course of the retinal vessels and often forming on the vessel walls. They are often star-shaped, or in a spider-like formation, giving the appearance of a net-work stretched over the fundus.

Detachment. Occasionally, for some reason (not always clear) the retina becomes partially detached from the choroid, and falls over, like a folded curtain. The normal reflex is absent at the detached portion, and in its place is seen a grayish surface of uneven, wavy character.

Atrophy. Usually accompanied by atrophy of the choroid. The white sclera is seen showing through as white patches.

ABNORMALITIES OF THE CHOROID.

The choroid, being a vascular coat, like the iris, is much more subject to inflammatory diseases than the retina.

Choroiditis. This is the commonest pathological condition met with in the choroid, and there are innumerable varieties of

the disease. Simple inflammation and hyperemia of the choroid, and even hemorrhages into the choroid, are difficult of recognition by any but an expert, because these conditions are concealed by the retinal coat. It is not until the inflammation has produced deposits and degenerations in the pigment that it becomes easily recognizable.

At this stage the cardinal ophthalmoscopic symptom consists of patches of brown or black, scattered over the eye-ground, which presently change to white, as the exudates are absorbed. The appearance of the eye-ground changes from time to time, new areas of pigment degeneration appearing, while others become white. Two general varieties of this form of choroiditis are recognized, according to the topography of the disease,—central, in which the degeneration lies around the disc, and disseminated, in which the patches are disseminated all over the eye-ground, especially toward the peripheries. Subjectively, there is diminution of vision. The trouble is usually due to some constitutional disease, most commonly to syphilis.

Myopic Choroiditis. One of the most serious types of choroiditis, and one which especially interests the refractionist, is that which is due to the stretching of the choroid tunic by high myopia. It is this which constitutes the grave factor in what we call progressive myopia.

Posterior Staphyloma. This is not, strictly speaking, a condition of the choroid, but a bulging backward, cone-fashion, of the sclerotic coat at the back of the eye; but it is the result of stretching and weakening of the choroid. It is recognized with the ophthalmoscope by the different power necessary to focus the bulged portion of the fundus.

Coloboma. Occasionally there is a congenital absence of a portion of the choroid and retina, due to arrest in development of the eye, similar to that which is sometimes seen in the iris, as though a piece had been cut out. It usually appears in the form of a triangle, with its apex at the disc. The white of the sclera shows strikingly where the choroid and retina are absent.

REFRACTION BY OPHTHALMOSCOPY.

The refraction of the patient's eye can be roughly estimated by means of the ophthalmoscope, either by the direct or by the indirect method.

Direct Method. If the operator's eye wears its proper distance correction, and has its accommodation thoroughly relaxed, and if the patient's accommodation is also completely relaxed, it is evident that the only other factor needed to obtain a clear view of the patient's fundus is that his eye shall be emmetropic, i. e., that the light waves emerging from it shall be neutral.

If, then, under the above conditions, we get a clear view of the fundus, we conclude that the patient's eye is emmetropic. If not, he has an error of refraction; and the lens, plus or minus, which, when wheeled into place at the sight-hole, gives us a clear view of his fundus, is the measure and correction of this error. If there is astigmatism, we shall find that it requires different lens power to give us a clear view of the fundus in the direction of the two chief meridians.

Indirect Method. Having obtained a good focussed image of the optic disc by means of our objective lens, we slowly move the objective lens away from the patient's eye toward our own, taking care to maintain our view of the disc-image, and note whether the size of the image undergoes any change.

If the patient's eye is emmetropic, i. e., if the emergent waves are neutral, then it is evident that, no matter at what distance from his eye the objective lens is held, the object (i. e., the patient's disc) will be situated at infinity on one side of the lens, and the image will be situated at the focal length of the lens on the other side; and the image will therefore remain the same size as we move the objective lens toward us.

If the patient be hyperopic, i. e., if his emergent waves be divergent, then, as we withdraw the lens, increasing the distance from object to lens, the size of the image will decrease inversely in reciprocals of focal lengths. The image, therefore, will seem to get smaller as we withdraw the objective lens toward our own eye.

Again, if the patient be myopic, i. e., if the waves emerging from his eye be convergent, then the object focal point and the

image focal point are both on the front side of the objective lens, and as we move the lens forward we decrease the distance from object-focus to lens, and the size of the image increases in reciprocals of focal lengths. As we withdraw the lens, therefore, toward our own eye, the size of the image appears to increase.

If the eye is astigmatic, the change in size of the image will take place only in the meridian at fault, or unequally in the two chief meridians.

One has only to read the description of the foregoing technique, to say nothing of putting it to trial, in order to see at once the extreme difficulty of fulfilling all the necessary conditions demanded by the direct method, or of making anything like accurate observations by the indirect method. As stated at the outset, no one in his senses would nowadays think of employing ophthalmoscopy as a means of estimating refraction, in the face of the difficulties and sources of error involved, and in view of the far superior procedures at his disposal.

Ophthalmostat. An eye speculum.

Ophthalmotosia. Protrusion of the eyeball.

Ophthalmotropia. Atrophy of the eye.

Ophthalmula. A scar of the eyeball.

Optic Atrophy. Atrophy of the optic nerve, with partial or complete loss of vision as a result. Under the ophthalmoscope the nerve-head (disc) appears as a sharply defined oval of dead white, surrounded with a dark border. It is a hopeless condition. (See **Ophthalmoscopy.**)

Optic Axis. See **Axis.**

Optic Commissure. See **Chiasm.**

Optic Disc. See **Disc.**

Optic Groove. See **Grove.**

Optic Nerve. See **Optic Tract.**

Optic Papilla. Same as **Optic Disc.**

Optic Tract. The nerve path by which the visual impulses travel from the retina to the brain. The optic nerve, consisting of fibres gathered up from the two lateral halves of the retina goes backward to the optic chiasm, where the fibres from each temporal half cross over to the other side. From that point the lateral half of each retina is represented on the corresponding side of the brain. Thence the tract proceeds backward to the quadregeminal and geniculate bodies, where the fibres terminate and deliver their impulses to a new set. The new tract conveys the impulses to the temporal lobe on each side of the brain, which is the center of pure vision. Thence the impulses are relayed by another set of nerve fibres to the left frontal lobe of the brain, where the visual impressions are interpreted. (See **Physiology.**)

Optical Center. The point on the principal axis of a lens at which the secondary rays cut the principal axis.

Optician. In its broad sense, this word signifies a person who is proficient in the study of the science of optics. In ordinary parlance, it is usually restricted to one who makes optical instruments.

Optics. The science of light in its broadest intent, including the physics, mathematics, and physiology of the subject.

Optogram. The image impressed upon the retina by the photochemical action of light.

Optometrist. One who measures the refraction of the eye and its muscular functions.

Optometry. The science and art of measuring the refraction and muscular conditions of the eye.

Ora Serrata. The anterior border of attachment of the retina to the choroid, so called because it has a zig-zag form like to teeth of a saw.

Orbicularis Ciliaris. See **Anatomy of the Eye.**

Orbicularis Palpebrarum. See **Anatomy of the Eye.**

Orbit. The bony socket in which the eyeball rests, formed of borders of the superior maxillary, frontal, lachrymal, palate, malar, ethmoid and sphenoid. The orbit is shaped somewhat like a cone, the apices being behind, where the optic nerve enters the eye. The extrinsic muscles are all attached to the orbit. (See **Anatomy of the Eye.**)

Orbital. Pertaining to the orbit.

Orthochromatic. Applied to vision which is normal for colors.

Orthometer. An instrument for determining the protrusion of the eyeballs.

Orthophoria. A state of normal function and balance in the extrinsic muscles of the eyes.

Orthoptic. Orthoscope. Applied to methods and instruments for the purpose of correcting heterophoria and strabismus, by means of prisms.

Orthoscopic Lenses. Combinations of lens and prism so adjusted that accommodation and convergence coincide.

Orthotropia. A condition in which, with the extrinsic muscles in passive equilibrium, there is normal parallelism of the visual axes of the eyes. Speaking simply, an absence of squint.

O. D. An abbreviation for the right eye (Oculus dexter).

O. S. An abbreviation for the left eye (Oculus sinister).

O. U. An abbreviation for both eyes (Oculus unity).

Pachyblepharon. Thickness of the eyelids.

Palpebra. The eyelid.

Palpebral. Pertaining to the eyelid.

Palpebral Fissure. The opening between the eyelids. See **Eyelids.**

Palpebritis. Inflammation of the eyelid.

Pannus. A growth of false tissue under the epithelium of the cornea, due to continued irritation, as by the granules of trachoma.

Panophthalmia. Panophthalmitis. Inflammation of the entire eye.

Pantoscopic. Applied to glasses which are so adjusted as to give the best vision, with the least prismatic effect, in all directions.

Papilla. A slight, round elevation of tissue. In the eye the optic disc is often called the papilla. The elevation in which is the opening of the lacrymal sac is called the lacrymal papilla.

Papillitis. Another name for optic neuritis.

Papillo-Retinitis. Inflammation of the retina and optic nerve.

Parablepsia. A condition of vision in which objects are seen distorted or different from what they really are.

Parachromatism. Color-blindness.

Parachromatopsia. Color-blindness.

Paradoxical Pupil. A condition in which the pupillary reflex behaves in an opposite way to normal, i. e., the pupil expands, instead of contracting, when a bright light is thrown into the eye. The phenomenon indicates a grave disease of the brain.

Parallax. The apparent change of place which objects undergo by being viewed from different points, or under different optical conditions.

As applied to lenses, it signifies the apparent movement of an object viewed through the lens, when the lens is moved to and fro laterally between the object and the eye. This apparent movement is due to the fact that a lens is in reality a series of prisms whose bases (in convex lenses) or whose apices (in concave lenses) meet at the center of the lens; hence, as the lens is moved before the observer's eye, so that he no longer looks through the optical center, it has the effect of a prism, and the image is apparently displaced toward the apex of the prism. (See **Prism.**)

In the case of a convex lens, the parallax movement is in the direction opposite to that in which the lens is moved; in concave lenses, in the same direction that the lens is moved.

When, instead of moving the lens to and fro between the eye and the object, we move our own head to and fro, the relative movements are the reverse of what was just stated. Or if we hold the lens so far away from our eye that we are outside of its principal focus, then the movements will be reversed, because the rays reaching our eye through the lens are reversed.

Parallax Tests. Tests which depend upon the parallax movements. There are two such tests common in ophthalmology:

(1) In glaucoma, when the optic disc is cupped, if we move the ophthalmoscope to and fro, laterally, the edge of the disc and the central portion appear to move at different rates of speed, owing to the difference of level between the edge and the bottom of the cup.

(2) The Duane, or cover test for muscle imbalance is also known as the parallax test. (See **Heterophoria.**) We can extend this test, after we have determined the existence of imbalance, by covering, say, the left eye, and having the right eye fix the object, and then suddenly uncovering the left eye. If the right eye remains steady, and the left moves into position, the trouble is a functional heterophoria. If the right eye moves out of position and the left moves into place, there is squint, and the left eye is the fixing eye. If neither eye moves, there is squint and the right eye is the fixing eye.

Parallelism. A state of being parallel. In optics the term refers to that state of the eyes in which the visual axes are parallel. See **Convergence.**

Paralysis of Accommodation. Paralysis of the ciliary muscle, so that accommodation cannot be performed. Such a condition may be due either to (a) some central nervous disease, or (b) poisoning of the short ciliary nerves. The former cause is extremely rare. The second form of paralysis we bring about artificially when we put atropine in the eye. Pathologically, it is almost always the result of some infectious disease, such as diphtheria, scarlatina, typhoid, etc.

Parinaud's Conjunctivitis. Conjunctivitis characterized by reddish granulations and swelling of the lymph glands in the ear and throat, said to be contracted from animals.

Paropsia. Same as **Parablepsia.**

Patheticus. A name given to the superior oblique muscle of the eye. (See **Muscles.**)

Pathologic. Pertaining to disease.

Pencil. The name given to a cone or cylinder of light rays containing all the color waves of the spectrum.

Penumbra. The area of partial shadow between the full light and the total shadow caused by an opaque body intercepting the light from a luminous body.

Perception. The physiological term given to the reaction of the brain to the sheer stimulus of a sense-organ. Thus, perception of light, or of an image, is the sheer knowledge that the retina is being stimulated by light or by an image, without any interpretation whatever. It does not even include projection of the stimulus to its source of origin.

Perichoroidal. Surrounding and adjacent to the choroid.

Pericorneal. Surrounding the cornea.

Peridhoroidal. Surrounding the choroid.

Perimetry. This term is applied to the measurement and outlining of the visual field, by whatever means it is carried out.

Although the pupillary aperture is circular, and the retina lies in a segment of a hollow sphere, the stimulated area of the retina, on which the light falls, and therefore the contour of the visual field, (which is but the inverted projection of the retinal field), are by no means circular. The retinal field does not extend equally in all directions. It extends furthest toward the nasal side, where it has a reach of 90 degrees; hence we can see objects on the temporal side of the visual field as long as they lie on, or even slightly behind, a plane passing through the pupil, i. e. almost at right angles to the visual axis where it is tangent to the cornea. This is possible largely because of the strong refraction undergone by rays falling on the cornea at this angle. Toward the temporal side and downward the

extent of the retinal field is much less, because of the interposition of the nose and the brow, cutting off the entry of light. The nasal and upper ranges of the visual field, therefore, are much more restricted than the outer.

The actual contour of the field may, of course, be varied by the way in which the head is tilted during the observation; however, the inner field is never, under any circumstances, as extensive as the outer. Ordinarily, the measurement and definition of the field is done with the head in a perpendicular, fronting position, and under these conditions the normal contour of the visual field is as shown in the accompanying illustration.

All methods of measuring the visual field consist in essentially the same process, namely, ascertaining the furthest peripheral point, along each of the meridians of the eye, at which a small object, entering the visual field, is first perceived. As the results obtained by any method of test will vary with the position of the patient's head, the size of the object used, the degree of illumination, and other circumstantial conditions, it is important that these conditions be well adapted to the test and made uniform for every examination.

CONFRONTATION TEST.

For clinical purposes, and in the absence of instruments of precision, a very fair rough estimate of the field may be obtained by the use of the practitioner's hand or finger. Practitioner and patient stand or sit, face to face, and on the same level, so that their pupils front each other. The distance between them should not be more than a few feet. The practitioner closes his right eye and the patient his left, for the examination of the patient's right eye. Both practitioner's and patient's eye are now in precisely the same relation to the visual field which is to be outlined.

The practitioner now puts his hand, or finger, out laterally so that neither he nor the patient can see it, and gradually moves it inward, toward the centre of the field, instructing the patient to speak as soon as it becomes visible. This is repeated along the various meridians of the eye. If the patient perceives the hand at substantially the same moment that the

practitioner does, his visual field in that meridian may be considered normal; if not until appreciably later, there is a contraction of the field in the meridian in question—hence an abnormality in the retinal area in the opposite meridian.

A little more accurate modification of this test, which is known as the confrontation method, can be obtained by substituting a small object, such as a tiny square of cardboard, mounted on a stem, for the practitioner's hand.

Perhaps a still more accurate and convenient method is that of the blackboard. A large circle and its meridians can be drawn on the board, the patient standing a few feet away, made to fix his eye upon the centre of the circle, and a small piece of chalk, for the object, moved inward along the meridians, successively, the point at which it becomes perceptible being marked on each meridian, and these points being joined up by a line at the completion of the test. By this means a very good outline of the visual field can be obtained.

THE PERIMETER.

All of these methods, however, have one objection, namely, that the retinal field, being concavely spherical, cannot be accurately projected onto a plane surface. The perimeter is designed to remedy this objection, and at the same time to make the mechanical features of the test more accurate and convenient. There are several varieties of perimeter made, but all are variations of the same principle.

Essentially, the perimeter consists of a hollow hemisphere disc, either whole or in section, mapped out into meridians, and the meridians, in turn, divided into short equal graduations, at each of which a tiny hole pierces the disc. There is a headrest for the patient's head, and a central point for fixation. As the object (usually consisting of a small piece of card or tin on the end of a stem) is brought inward along each meridian, and the patient gives notice that he perceives it, the point of perception is marked by thrusting a pin through the hole in the disc, which perforates a chart inserted at the back of the disc. When this procedure has been carried out for all the meridians, the perforations on the chart give a substantially accurate outline of the patient's visual field. The charts usually contain a printed outline of a normal field, so that the

perforated outline automatically compares itself with the normal.

THE COLOR FIELD.

The extension of the retinal and visual fields is not uniform for colors. The peripheral portions of the retina are virtually color-blind, so that when a colored object is moved gradually into the visual field it is first perceived merely as an object without color. Not until it is moved well in toward the central portion of the field does its color become perceptible. Blue is recognized the earliest; that is to say, blue has the largest visual field; green has the smallest; red is somewhat larger than green; and yellow, again, is a little larger than red.

Thus, if the result of the test with colors be normal, the perforated chart will show the outline of the blue field on the outside, the yellow outline inside the blue, the red inside the yellow, and the green inside the red; all of them substantially concentric with each other. Any different relations will indicate disturbance of the retina.

For ordinary purposes, testing with black and white, i. e. with a white object on a black field, is sufficient. Tests with colors have the following advantages: (1) They are more delicate tests; disclosing retinal defects before they have sufficiently progressed to cause any loss of vision for black and white, (2) They give information concerning the color sense itself, and (3) There are certain diseases of the retina which are to be diagnosticated by distortions of the color field. Conspicuous among such diseases is toxic amblyopia, in the early stages of which there are no gaps in the visual field when tested with black and white, but green and red grow very indistinct (and later disappear altogether) as they reach the centre of the field.

CONTRACTIONS OF THE VISUAL FIELD.

When the object has to be brought nearer to the centre than normal before the patient perceives it, the field is said to be contracted in that meridian. Contractions of the field are of three general types: (1) Concentric, in which there is a uniform contraction in all meridians, so that the size of the field is diminished, but its contour unchanged, (2) Sector-

shaped, in which there are contractions in separate meridians, making triangular cuts into the contour of the field, and (3) Hemiopic, in which an entire half of the field is wanting (half-blindness).

Concentric contractions of marked degree are usually due to hysteria and other functional nervous troubles. Sector-shaped contractions are invariably due to organic diseases of the retina. Hemiopic contractions are, of course, the result of lesions which impinge on the optic tract where one-half of each retina is represented, i. e. from the optic chiasm to the occipital lobe of the brain.

SCOTOMATA.

The blind areas of the visual field represented by the interruptions under the second variety of contractions, due to organic diseases of the retina, are technically known as scotomata. It is to be borne in mind that this interruption need not necessarily occur at the peripheral part of the field, i. e. on the entry of the object into the visual field. As the object is brought inward along a certain meridian, it may be well perceived at the normal point of approach, but as it is brought still further inward, toward the centre of the field, it may go out of vision again. In that case we speak of the blind area as a central scotoma.

Subjectively, scotomata are classified as positive and negative. A positive scotomata is one which the patient himself perceives as an area of darkness projected into his visual field. A negative scotoma is one whose hiatus in the visual field is not perceived, either because it is compensated for by the vision of the other eye, just as the blind spot of the optic disc is, or for some other reason. A negative scotoma is usually not discovered until an examination is made of the visual field by means of a perimeter; it then becomes manifest, just as the blind spot of the disc does.

INFLUENCE OF REFRACTION ON THE VISUAL FIELD.

In myopia, with its relatively long eyeball, the extent to which the rays of light from the lateral part of the visual field can be refracted so as to fall upon the sensitive portion of the retina is considerably restricted. In myopia, therefore, there

is an appreciable concentric contraction of the visual field. In hyperopia, with its shortened eyeball, precisely the opposite state of affairs exists; hence a hyperope's field of vision is concentrically enlarged. For these reasons it is desirable, in making examinations of the visual field, to have the patient properly corrected for distance with a sufficiently periscopic pair of lenses.

Periocular. Surrounding or adjacent to the eye.

Periophthalmic. Same as Periocular.

Periorbit. The parts surrounding the orbit.

Periorbital. Surrounding or adjacent to the orbit.

Periorbitis. Inflammation of the periorbit.

Periphacitis. An inflammation of the tissues surrounding the crystalline lens.

Periphacus. The capsule surrounding the crystalline lens.

Periphakitis. Inflammation of the parts surrounding or adjacent to the crystalline lens.

Peripheraphose. A sensation of dark spots in the peripheral field of vision.

Periphery. The outer margin or circumference of a circle or sphere. By extension, the part of a system furthest removed from its functioning centre.

Peripupillometer. An instrument for measuring the extent of the pupillo-motor area of the retina and the value of the pupillary reflex.

Periscope. An instrument which, by means of prism refraction and mirrors, enables one to view an object that is outside of his line of vision. It is of no special interest to the refractionist.

Periscopic. A term applied to a lens which is curved to conform, as far as possible, to the arc of rotation of the eyeball, so that

which ever way the visual axis is directed it will pierce the lens almost perpendicularly. See **Lens.**

Peritomy. An operation for pannus (q. v.) by cutting a strip of conjunctiva out so as to cut off its nourishment.

Perscorvinus. A wrinkled condition of the inner canthus, commonly known as crow's foot.

Perspicilium. Any instrument which improves vision.

Petit's Canal. The space, triangular on cross section, included between the fibres of the zonula and the equator of the lens.

Phacomalacia. Soft cataract.

Phacometer. An instrument for measuring the curvature of lenses, determining their refractive power, and, if cylindrical, locating their axes.

Phacosclerosis. Hardening of the crystalline lens.

Phacoscope. An instrument for viewing the crystalline lens and its functioning.

Phlyctenular Conjunctivitis. A form of conjunctivitis in which there are tiny blisters or blebs on the membrane.

Phlysis. A corneal ulcer.

Phoria. The position of the eyeball in relation to its visual axis. In common optical parlance the word "phorias" is used to indicate the various types of muscular imbalance.

Phorometer. An instrument for detecting and measuring imbalance of the extrinsic ocular muscles. It consists essentially of two prisms of moderate power—say 6 dioptres each—geared so that they can be rotated simultaneously in opposite directions. The prisms are first set with their bases in, so that the patient, on looking through them at an object six meters away, will see two images, each image on the same side as the eye which perceives it. If his vertical muscles are in equilibrium the images will be on the same level; if he have right hyperopia, the right image will be lower; if left hyperopia, the left

one will be lower. In case the images are not on a level, the prisms are rotated until they do so stand; the amount of hyperphoria can then be read off on the scale.

To test the lateral muscles the prisms are rotated until their bases point up and down, respectively; the images are then doubled vertically. If there is orthophoria, they stand in the same vertical line; if there is esophoria, they are separated laterally in the same direction as the eyes which perceive them; if exophoria, they are separated in the opposite direction. The prisms are then rotated so as to bring the two images into one vertical line, and the amount of error read off on the scale.

There are several phorometers on the market, differing from each other in mechanical principle and technique.

Phosphene. The sensation of a bright border around the visual field during a sudden relaxation of accommodation in the dark, said by Czermak to be due to dragging on the retina about the ora serrata.

Pressure Phosphene. A similar sensation caused by pressure on the eyeball.

Photalgia. Pain in the eye produced by light.

Photesthesia. Extreme sensitiveness to light.

Photogene. A prolonged retinal image.

Photometer. Photoptometer. An instrument for testing the sensitiveness of the eye to light by determining the minimum illumination under which an object becomes visible.

Photonosus. Any disease of the eye resulting from glare of light.

Photophobia. Intolerance of light. This condition is a symptom in most inflammatory diseases of the eye.

Photophthalmia. Any disease of the eye due to exposure to excessive light, such as snow-blindness, lightning stroke, solar cataract, etc.

Photopsia. A subjective sensation of light.

Photoptometry. Measurement of sensitiveness to light.

Photoradiometer. An instrument for determining the power of penetration of light.

Phthisis Bulbi. Atrophy of the eyeball.

Physiology of Vision. The function of vision may be divided into three phases, or stages: (1) The mechanism by which light waves are made to focus upon the retina, and the central rays to fall coincidently upon the two maculae, so as to produce a clear and single image. (2) The process by which light energy is transformed into a nerve impulse and transmitted to the brain. (3) The mental process by which the image-picture so produced is interpreted and acted upon.

(1) The first phase consists of (a) the refraction, static and dynamic, of the eye, and (b) its motility. The static refraction of the eye will be found discussed at length under the heading of **The Eye,** and, indeed, forms the subject of many sections of this book. Suffice to say here that the cornea, the aqueous humor, the crystalline lens and the vitreous together form a compound lens system which in the normal eye at rest, is exactly adapted to focus neutral (infinite) waves upon the retina.

Dynamic refraction consists of an active effort on the part of the eye to increase its refractive power by increasing the convexity of the crystalline lens, through contraction of the ciliary muscle, in order to focus convergent (finite) waves upon the retina. This it does in obedience to an imperative desire of the brain for a clear image. The process will be found fully treated under **Accommodation,** and the nervous mechanism by which it is accomplished will be described at length later in this article, when considering the eye reflexes.

The motility of the eye, i. e. its rotation on its various axes by means of the extrinsic muscles, is for the purpose of directing the maculae toward the object looked at, so as to ensure singleness of the central image. This, in obedience to an imperative desire for a single image. These movements are of two kinds: (a) Conjugate, where the two eyes are moved in the same direction, to the right, to the left, up or down.

(b) Coordinate, where the two eyes are turned inward or outward.

Conjugate movements up and down are performed by the pairs of superior and inferior rectus muscles, respectively; horizontally by the internal rectus of one eye and the external rectus of the other. The obliques modify all these movements. Coordinate movements are performed by the internal recti and external recti, respectively, in concert, modified by the obliques. A full discussion of these latter movements will be found under **Convergence,** by which name their action is known. It is generally assumed that there is a special cerebral centre for negotiating the act, known as the fusion centre; its existence, however, is not proven.

Coordinate movements inward (positive convergence) are usually accompanied by conjugate movements downward, and coordinate movements outward (negative convergence) by conjugate movements upward, so that these two forms of conjugate movements are generally regarded as part of the function of convergence, of which, however, they are not properly a part. Occasionally horizontal conjugate movements are combined with positive convergence; the eyes looking to one side and converging at the same time; and this combination is a little difficult of explanation.

It is rather hard to see how the internal of one eye and the external of the other can be innervated so as to make one form of movement, and the internals of both eyes to make another form of movement, simultaneously. Nevertheless, we know that they are. However, the combination is evidently somewhat of a **nervous** strain, for the power of convergence diminishes in proportion as the eyes are turned to one side. Indeed, conjugate movements are apparently tiresome acts, anyway, which the individual avoids as much as possible, preferring to turn his head rather than his eyes.

(2) Thus far the eye has the character and plays the part of a movable and adjustable lens or camera. The real physiology of vision begins with the falling of the focussed waves of light upon the sensitive film, or retina.

THE OPTIC NERVE TRACT.

The optic nerve tract consists of two groups, one group for each eye, of several thousand neurons, whose cells lie distributed over each retina, in the rods and cones of Jacob's membrane. Their axis-cylinders, in each case, are gathered together in a bunch, like strands of silk bound into a rope, surrounded by a strong white sheath, to form the optic nerve, and travel backward to the mid-brain. In each eye, the axis-cylinders gathered from the two lateral halves of the retina, i. e. the nasal and temporal half, remain on the corresponding side of the optic nerve until some inch or so back of the orbit, where the two nerve tracts come together and undergo a semi-crossing of their neurons.

Here the neurons from the inner or nasal halves of the retinae cross over to the opposite sides, while those from the

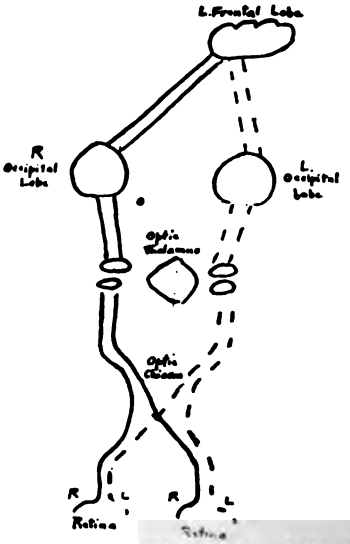


Fig. 1. Showing the optic tract. Note the semi-crossing of the neurons at the chiasm, so that each half of the retinae is represented on the same side of the brain. The neurons are relayed at the optic thalamus, and all are reunited at the left frontal convolution.

outer or temporal halves remain on the same sides; so that beyond the crossing-place we see all the neurons from the [illegible] half of each eye on the right side of the brain, and th[illegible]

the left half of each eye on the left side of the brain. The place where they cross is called the optic chiasm. (Fig. 1.)

After this crossing (technically known as decussation) the two tracts travel still further back to the mid-brain. Here there is an important sub-station, consisting of several groups of nerve ganglia, among them the geniculate and quadrigeminal bodies. The largest of them, however, is a diamond-shaped ganglion which gives its common name to the entire sub-station—the optic thalamus. At the optic thalamus all the optic neurons end, and deliver their impulses to a new relay of neurons. It may be remarked, in passing, that all the neurons of every sensory tract in the body, including the great spinal tracts, the auditory tract, etc., arrive at this same junction place, and all end there and relay their impulses to fresh neurons. It will therefore appear that it is a very important sub-station in the brain.

From the optic thalamus the optic neurons divide. Some of the relay neurons go backward and downward to the fourth ventricle, just above the medulla oblongata, for a purpose to be related presently; others go back to the occipital lobe of the brain, at the extreme posterior part, where the centre of pure vision is located, and there register the sensation of light. This, it is to be understood, is the case with the tract on each side of the brain.

From the occipital lobe, the impulse is again relayed, by another set of neurons, from both sides of the head, to the left frontal lobe, in the very forepart of the left side of the brain, to the centre of mind vision, or visual memory, where the image is perceived and interpreted.

This gives a brief, concise account of the visual tract, and the course of the visual impulse from the retina to the brain, which a view of the accompanying cut will help to make clear.

It is evident, from the above statements, that the eye is not governed by the opposite side of the brain, as is the arm or leg. Nor is it governed by the same side, as are the face and head. Its nervous mechanism is a sort of mixture of direct and opposite control. The left side of the brain is represented by the right half of the cornea and lens, and the left half of the retina, in each eye; the right side of the brain, by the left half

of the cornea and lens, and the right half of the retina, in each eye. (It will be remembered that the light-waves are inverted between the cornea and the retina.) The net result, however, is that the right brain perceives objects on the left of the individual, the left brain objects on his right.

THE VISUAL IMPULSE.

The neurons of the optic nerve are light neurons, i. e. they are designed to be stimulated by light vibrations and to register in the brain the sensation of light. Like all the sensory nerves, however, they are capable of stimulation by almost any kind of physiologic stimulus, but register always the same sensation. Thus we can stimulate the optic nerve, in a crude fashion, by means of heat, or cold, or pressure; but the sensation produced is not heat, or cold, or pain, but flashes of light.

Normally, however, the optic nerve is stimulated by light. The objects of the outer world throw their images on the retina; it is the part of refraction to see that this image is clearly focussed. It is the function of the retina to transform the light vibrations into a different kind of vibrations, viz., nervous excitations, for transmission along the optic neurons to the brain, a process analagous to that which takes place in the telephone, where sound waves are transmuted into electrical waves for transmission along the telephone wires.

The place at which this transformation takes place in the eye is in the rods and cones of Jacob's membrane. The precise manner in which it is made is not known. That remains one of nature's secrets, not only in respect of the retina, but of every nerve-end. We know, however, that most of the energy of the light vibration is used up in producing certain chemical changes in the rods and cones; hence we are warranted in concluding that these changes represent the physical generators of the nerve current.

It was a German physiologist named Boll who first made the important discovery that the retina of most animals (including man) appears of a purple-red color, and that during life this color constantly disappears under the influence of light. Further observation showed that the color is not depend[illegible] upon structural relations, but is due to a pigment whic[illegible] om-posed by light. This pigment is called the visua[illegible] or

rhodopsin; and it is the decomposition of the visual purple, principally, which sets up the nervous stimulus in the endings of the optic nerve.

The visual purple, it is broadly stated, resides only in the rods. This is not strictly accurate; for there are cones which contain it. As a general proposition, however, the statement may stand, that the rods contain visual purple and the cones are devoid of it. Every color wave in the spectrum has the power of decomposing the visual purple—technically known as "bleaching," because under decomposition the pigment becomes successively yellow and white. The higher the color wave, the more rapidly it decomposes the purple; violet waves decompose it most rapidly, red the least. In the dark, or dusk, the visual purple remains unchanged; and colors, as everyone knows, are not perceived in semi-darkness, although line and form are still quite recognizable.

In the macula there are no rods, but only cones, and no visual purple. In this area the sense of color is subordinated to the keen discernment of line and form.

After being decomposed by light, the visual purple is regenerated under the influence of darkness, or partial darkness, by the epithelial layer of the retina.

IMAGES AND THEIR PROJECTION.

Images thrown by the refracting media on the retina, when they are well-defined, leave well-defined patterns on the layer of the purple rods—photographs, as it were, or optograms. It is possible to make these optograms on the retina for even a short period after death, especially in lower animals. They can be produced in the fresh eyes of rabbits and cattle.

The outlines and boundaries of these patterns on the retina determine the shape and form of the image as perceived by the brain, in virtue of what is known as the faculty of projection, i. e. the power of the brain to trace back every sensation along the path by which it came to the point where the stimulus entered the body. Thus, in the case of a retinal image, the brain traces back the composite sensation made by this pattern-area of retinal stimulation, along each separate neuron, and reconstructs the pattern.

As a matter of fact, the brain traces the image-sensation still further than that, back to the place where the waves of light entered the eye, i. e. to the cornea; so that the image which the brain projects and reconstructs is the corneal image, clarified by refraction and visualized by the retina. This simple fact—and not any of the fantastic theories frequently propounded—explains why, with an inverted retinal image, the brain sees objects upright. It simply projects the light rays back the way they entered the eye.

Projection, so far as it is an integral part of a sense itself, cannot go further than the point where the stimulus entered the body. Therefore, the sense of vision, of itself, cannot project the image any further than the surface of the cornea. Its further projection out into space, to coincide with the special position of the object, is a rather complex operation of the brain, in which others of the senses, also memory and experience, play a considerable part. We shall have more to say on this point later. It is this projection of the visual image into space that makes vision an external sense.

THE RETINAL AND VISUAL FIELDS.

The area of the retina on which light falls from the outer world, when there is no abnormal interference, is called the retinal field. This field is, of course, limited and shaped by the anatomical conditions of the face and the eye. In general its angular dimension is fixed by the size of the pupil, which, as the nodal point lies close behind it, permits a very wide visual angle. The dimension of the retinal field is determined by the size of this angle.

The shape of the retinal field is also substantially the shape of the pupillary opening, except on the nasal side of the retina, where the prominence of the nose cuts off a portion of the light from entering. The actual contour of the field, therefore, is as shown in the accompanying cut. (Fig. 2.)

Light from the right side of the outer world falls on the left half of the retinal field; and vice versa. The macula, being always at the retinal extremity of the visual axis, is always at the centre of the retinal field. At this place the acuity is greatest and the retinal field most clearly and strongly defined;

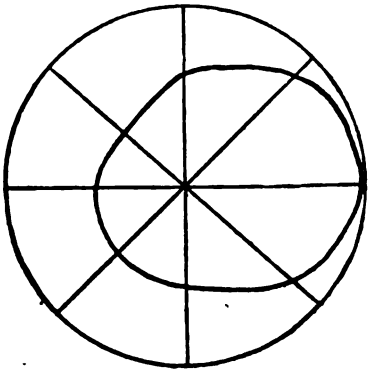


Fig. 2. Showing the contour of the visual field of the left eye. Note the cut-off due to interposition of the nose.

from there out to the circumference the rods and cones become less and less sensitive, and vision less and less distinct.

The retinal field is outlined by means of a device called the perimeter. It consists of a large concave disc with a central target from which radiate meridianal lines. While the subject fixes the central target with his eye, a small object (piece of card on a long thin stick) is slowly moved from the circumference of the disc inward along one of the meridians until it comes within the subject's vision. This is done successively along the meridians, a mark being made on the meridianal line (or on a chart behind it) to record the point where the object first became visible. These marks are then joined up all round the disc, or chart, and the resulting outline gives the contour of the retinal field. (See **Perimeter.**)

The visual field is the outer, objective complement of the retinal field, i. e., the area in the outer world from which light falls on the retina and stimulates it. The right visual field is represented on the left retinal field, and vice versa. Light from the centre of the field falls on the macula. Only that part of the visual field which is represented on the macula is viewed with attention and clearness; for only there do the images fall on identical points of the two retinae, and only there is the visual acuity sufficiently developed to perceive detail (See "The Visual Impulse"). The rest of the field, which falls on the outer portions of the retina, does not fall upon identical

points, and is therefore seen double; and the rods and cones are not sufficiently sensitive to recognize detail. However, the perception of this part of the field is good enough to enable us to see our way around, and to call our attention to any object which we wish to fix, so that we may turn our maculae toward it.

Again, owing to the interruption to the light by the prominence of the nose, and to the fact that images do not fall on identical spots in the retinae except at the maculae, one part of the visual field (that which falls on the maculae) is accurately superimposed—a printer would say it "registers true"—and is seen singly by the two eyes in fusion; other portions overlap in the two retinae and are seen indistinctly and blurred; still others (those which fall on the parts of the retinae cut off by the nose) appear only on one retina and not on the other. All this overlapping and unequal distribution of the visual field on the two retinae, however, does not bother the vision, because it affects only the outer area and not the central vision. As soon as we turn our maculae toward an object to view it attentively, that object does not overlap.

There is, moreover, a dark area of no vision at all in the visual field of each eye, corresponding to the small portion which falls on the blind spot of the retina (the optic disc); but as this dark area represents a different portion of the visual field for each eye, the portion that one eye does not see the other one does, and so it is not noticed.

EYE REFLEXES.

In describing the optic nerve tract it was stated that at the optic thalamus the neurons divide, one group going back to the centre of pure vision in the occipital lobes of the brain, another group traveling downward to the fourth ventricle. This latter course forms the path of what is known as the light reflex, for bringing about contraction of the pupil, as a protection to the retina against excessive light.

When light is thrown upon the retina, stimulating the rods and cones, the impulse, as we have seen, is carried backward along the optic tract to the optic thalamus. From this point, a part of the impulse goes to occipital lobes, registering the

sensation of vision, and part to a centre in the fourth ventricle, just above the medulla oblongata. This centre is practically a spinal centre, serving as an automatic arc, where the impulse is transferred to a motor neuron, the third cranial nerve, or motor oculi, whose root is in the fourth ventricle. The impulse is carried by neurons of the third nerve out to the ciliary ganglion, where it is delivered to the ciliary neurons of the sympathetic, and by them conveyed to the concentric muscles of the iris, causing them to contract and diminish the size of the pupil. This constitutes the light reflex. It is absolutely automatic and involuntary, taking place with unfailing constancy, even during unconsciousness, in a healthy individual. Its absence always indicates a grave pathological condition, in which the nerve path is blocked, either by disease or by drug poisoning.

Another important reflex of the eye is the accommodation reflex, for the purpose of contracting the ciliary muscle. The stimulus in this case is the falling upon the retina of an indistinct image; the impulse is carried along the entire optic tract to the centre of mind vision in the left frontal brain; there it is transferred to one of the motor projection neurons of the brain and taken down to the fourth ventricle, relayed to the motor oculi, by which it is carried to the ciliary ganglion, and delivered to the ciliary neurons of the sympathetic; these carry it to the ciliary muscle, and cause the muscle to contract for the purpose of accommodation. (Fig. 3.)

The accommodation reflex is not, strictly speaking, an automatic reflex, since its transfer arc is in the voluntary area of

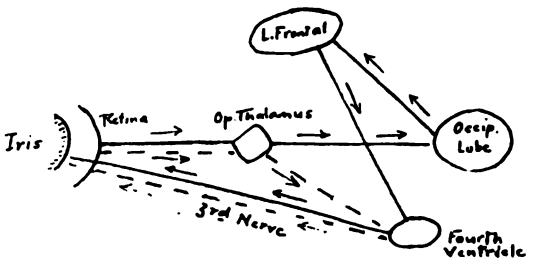


Fig. 3. Showing the path of the accommodation reflex (in unbroken lines), and that of the light reflex (in broken lines.)

the brain and it can be withheld at will. One does not have to accommodate in response to an indistinct image, as he has to contract his iris in response to light. However, the act, as ordinarily performed, is so instinctive and unconscious, in obedience to the imperative desire of the brain for a clear image, that it is generally regarded as a technical reflex. It occurs, of course, only during consciousness; and its absence, like that of the light reflex, is a sign of serious disease. It is, in fact, less often interrupted by disease than the light reflex.

In certain nervous diseases, notably locomotor ataxia, the light reflex is abolished while the accommodation reflex remains intact; so that the pupil fails to contract in response to light, but contracts during accommodation. Such a condition is known as an Argyll Robertson pupil, after the man who demonstrated it. In other diseases, the pupil responds to light but not to accommodation, and is then known as a Wernicke pupil.

The eyes negotiate several other so-called reflexes, none of which, however, are genuine, automatic reflexes, but, like the accommodation reflex, take place through the intelligent centres of the brain, so instinctively and instantaneously as to partake of the nature of true reflexes. Of these, the one which approaches most nearly to a true reflex is the act of winking when an object is brought very near the eye. The path taken by this reflex is the same as that taken by the accommodation reflex, except that it travels along different neurons of the motor oculi to the muscle of the eyelid. This act of winking in response to vision must not be confounded with the automatic act of winking which is kept up continuously for the purpose of cleaning the eyeball. The latter is a genuine reflex, which, however, has nothing to do with the optic tract. Its stimulus is the irritation of the conjunctiva and cornea, and the impulse travels by way of the sympathetics and the fifth cranial nerve to the fourth ventricle, where it is transferred to the motor oculi.

Other pseudo-reflexes, which we perform every hour of the day in response to stimulation of the retina, are those which are transferred at the centre of mind vision to other centres

and given to motor neurons going to various muscles of the body; as when we avoid a blow which we see coming, or get out of the way of a car, or laugh at a funny scene, or cry at a sad one, etc. None of these eye reflexes, except the light reflex, is a genuine, automatic reflex, and they occur only during consciousness.

VISION AND EQUILIBRIUM.

Mention has been made of the part which vision plays in the faculty of co-ordination, i. e., of maintaining equilibrium. We stand, and walk, and perform other muscular acts, continually, by the aid of our vision, which keeps us advised of spacial relations. In the use that we habitually make of it, vision is a most important factor in co-ordination. In another sense, it is not nearly so important a factor as the muscle sense and the semi-circular canals of the ear; namely, that if we are deprived of vision it has very little effect on our co-ordination and equilibrium; we soon learn to do without it. The other two factors we could not do without. A very striking example of the way in which vision controls our nervous balance is to be seen in the different way in which a sudden shock affects us according to whether or not we see it coming. If, groping around in the dark, we suddenly lay our hand on a cold, wet rag, it makes us jump; but if we had seen it just before we touched it, we should receive the sensation quite calmly.

PURE VISION.

The first place at which the visual impulse, carried back along the optic tract, registers a sensation, is at the occipital lobe of the brain, in the very back of the head. The sensation registered here is sheerly that of perception. Each lobe, on either side of the brain, perceives half the visual field, since it receives neurons from one-half of each retina; so that both must be functioning in order to see a complete picture. Occasionally we meet with a disease of the brain which destroys one of these lobes, and then the patient is blind to one side of the visual field; such a condition is called hemianopsia, or half-blindness.

If the impulse got no further than the occipital lobes, or if the rest of the optic tract, beyond the occipital lobes, were

impaired, vision would be sheer perception and nothing more. We should see objects, to be sure, but they would have no meaning for us, nor even any spacial relations. Nor should we ever remember what we saw; every time the image fell on our retina, it would be new to us. Our vision, therefore, would do us no good. Occasionally we meet with patients who are in just this condition. Delirious people are temporarily in this state; certain forms of idiotcy permanently so. Even a normal person occasionally experiences a fleeting instance of it—for example, just as he awakens from a sound sleep, until he "gets his bearings." In order that the perceived picture may have any meaning and value, it must be transmitted to, and acted upon by, the higher brain centres.

Pure vision, then, is only a complemetary part of vision—but an important one. Without the higher centre it would be without any meaning or value; on the other hand, without the centre of pure vision the higher centre would have no image to interpret.

MIND VISION.

The impulses received by the occipital lobes are relayed by them, along fresh neurons, to one single centre in the left frontal convolution in the brain, located just posterior to the fissure of Rolando, a few inches back of the forehead. This is the centre of mind vision. What happens here is a very complicated affair which would take volumes to discuss fully. We shall discuss it very briefly and generally.

The functions of this higher centre of vision may be roughly divided into four, although each of the four is itself a multiple and complex performance:

(1) Visual Memory. This is the simplest and earliest of the higher visual functions. It consists essentially in the storing of repeated images, until the brain becomes familiar with, and recognizes them. This is a necessary preliminary to whatever other operations the brain may have to carry out in regard to its images; and it is this, chiefly, that the visual centre of the infant is concerned with during the first year or so of life, although, to a less extent, we continue to do it all our lives.

Just what the nature of this memory process is, it is impossible even to guess. Most likely it is analagous to the learning of a code in telegraphy, each kind of image registering a special kind of impression, which, after repeated registering, meets with a sort of automatic response in the brain centre. This, however, does not explain the power of the brain to recall the impressions at will, without any stimulus from the retina at all, which forms a part of the memory faculty. We must just leave it unexplained.

(2) Visual Classification. This is the faculty of resolving images into their attributes and qualities, color, form, number, etc., and comparing them for their likeness or unlikeness. The nature and mechanism of this faculty is quite beyond any attempt to explain. It, also, is a faculty with which the child is very busy in its early life.

(3) Visual Judgments. This faculty consists in comparing the data furnished by the image itself with the data derived from others of the senses, touch, muscle sense, etc., and thereby arriving at certain conclusions which are not really a part of the function of vision at all, but so intimately bound up with it as to be generally regarded as a part of it; the size of the object, its distance from the eye, its solidity. The way in which these judgments are formed will be further discussed presently.

(4) Visual Associations. This is the highest and most complex, as it is the most valuable, of the visual faculties. In the performance of it, the visual centre goes into conference, as it were, with all the other higher centres of the brain, and associates the image with all the other experiences, past, present and future, that have any sort of connection with the object for which the image stands. This, of course, is the ultimate end of vision, which enables us to utilize the visual function for the purposes of living. Without it, the value of vision would be exceedingly restricted. We would, for instance, be able to see and recognize an automobile in the street, and even to calculate very accurately its distance from us, but we should be utterly unable to avoid it, because we should be unable to co-ordinate all this information with the other ideas necessary

to get out of its way. Or we might be able to see a beautiful picture, or sunset, and even to enjoy a pleasurable sensation of its beauty; but it could not awaken in our minds all the train of associated ideas which would move us to joy or to tears. So, both from the utilitarian and from the esthetic standpoint, visual association is the most valuable of all the higher visual faculties of the brain.

It is highly probable that not one of these higher visual faculties is performed by the centre of mind vision itself. Most likely, the centre in the frontal convolution merely serves as a point of registration, which is on a telegraphic circuit, so to speak, with all the other brain centres (through the association and commissural neurons) and the entire brain takes part in the performance of the visual faculties. This is likely to be the case because precisely the same series of faculties have to be exercised by the brain in regard to every one of the senses in order to make them of any working value to the individual. It is probable, therefore, that the cerebrum is a clearing house, to which all the brain centres refer their impressions for their appropriate interpretation.

VISUAL JUDGMENTS.

A general account of physiologic judgments has already been given in the section on general nervous physiology, and a brief description of visual judgments in the section on mind vision. We must now consider these latter in a little more detail. They are so closely bound up with the function of vision as to be almost an integral part of the sense itself.

There are three important conclusions which the mind has to form concerning the objects which it views, and which the sheer perception of the image itself does not afford. In order to arrive at these conclusions the brain is obliged to utilize the information afforded it by other senses, and from other sources.

(1) Judgment of Distance. From a utilitarian point of view this is perhaps the most important of the visual judgments, since it enables us to adjust ourselves in our active relations with objects around us—to go to them, to avoid them, to reach out and handle them, to arrange them, etc. Three factors

enter into the formation of the judgment of distance: muscle sense, the visual angle, and experience. The first pertains to accommodation and convergence. The nearer an object is to us, the more muscle contraction we have to exert in the ciliary and rectus muscles in order to see it clearly and singly. By the sense of this muscle contraction we form a judgment of its distance. The second has to do with the apparent dimension of the object from one extreme boundary to the other, subtending the visual angle. This we compare with other objects whose distance we know and form a conclusion as to its probable distance. The third factor comprises all that we have previously experienced which may help us in arriving at a conclusion. This last factor, of course, operates also in the case of the first two.

Of the three factors, the muscle sense is the most accurate and reliable; but, of course, its operation is restricted to objects that are within a person's far point. Beyond his far point, he does not use accommodation or convergence, and therefore has no muscle sense to go by. The result is that inside of one's far point judgments of distance are very accurate; beyond it, they are, at best, only vague and approximate. Everyone knows that, as he looks down a fairway of any kind, every point and object within about 20 feet he can quite definitely locate, and could easily touch them if he had a pole long enough; beyond that distance, he could only touch somewhere near them.

The second factor, the visual angle, has also a limited usefulness. In order to judge by it at all, there must be several objects of known size and distance, with which one is familiar, at hand for comparison. How important this is will very quickly appear when one tries to judge distance or size without such familiar objects available. A familiar example is to be found in the difference in the apparent size and distance of the moon when it is just above the horizon, and when it is high in the heavens. The explanation is that when it is low, we view it in association with familiar objects—trees, houses, churches, etc.—whose size and distance we know, and, knowing the vast distance of the moon as compared with their's, we imagine it

looks very large. When it is in the zenith we view it all by itself, with nothing but our memory of things to compare it with, and it appears smaller.

When the distance in question is very great, i. e., when the visual angle is very small, its value in forming judgment of distance is nil. We cannot form judgments of objects a mile or two away except by pure reasoning from experience.

At long distances, therefore, memory and experience are our only available factors for forming distance judgments; and such judgments are exceedingly vague and inaccurate.

Still another factor commonly utilized in every-day life for judging distance is the extent of territory and the number of familiar objects which lie between us and the object viewed. This, however, is hardly a visual judgment. It is a process of reasoning.

(2) Judgment of Size. Strictly speaking, there is no such thing as a judgment of size in the visual function, because, so far as sheer vision is concerned, there is no such thing as the size of an object, but only the size of an image; and that needs no judgment. What we really do when we make a judgment of size is to judge of the relative size of a certain image as compared with the image which an object of known dimensions would make if it were placed at the same distance from our eye, a yardstick, for example. Judgment of size, therefore, is really a judgment of distance, coupled with memory and experience of another object. Size is not a primary quality of an object; it is a phase of distance.

(3) Judgment of Solidity, or the Third Dimension. In judging of solidity, the brain makes use of two factors, distance and the binocular visual field. If an object be solid, its projected parts will be further from our eyes than its frontal parts, as we shall conclude from the use of our accommodation and convergence, if it be within our far point, and by the difference of visual angle (what the artist calls perspective). Further, since the outer parts of the image fall on different areas of our two retinae (see "Visual Field") and some parts of it do not fall on both retinae but only on one or the other, the images which we get of a solid object on the right and

left retinae respectively will be quite different. (This is easily proved by shutting first one eye and then the other in viewing a solid object.) By both of these factors, when the object is within our far point, and by the latter alone when it is beyond infinity, we form a judgment of solidity. At very long distances both factors fail us, and judgment of solidity is then impossible. We then only know that an object is solid because we recognize it as a familiar object, this recognition being based on previous experience.

In common with all physiologic judgments, visual judgments never err; and for this reason they are readily made the media of apparent deception. Upon this fact are based all the illusions of the artist's pencil, the painter's brush, and the stage, and anyone with ingenuity can work out for himself a hundred amusing devices to deceive the brain through the visual judgments. One of the most familiar of such deceptions is the stereoscope, which deceives the brain into thinking that a plane picture has solidity by presenting to each retina a different view of the scene, corresponding to the different views which the solid objects themselves would present, and by means of a pair of prisms, base in, compelling the viewer to use convergence of a different degree for various parts of the picture.

COLOR PERCEPTION.

The perception of color is an integral part of the sense of vision; that is to say, it cannot be separated from the performance of the act of vision, and the sensation of color cannot be separated from the sensation of light.

The subjective, or physiological, aspects of color are not so well understood as its objective, or physical, side. It is generally supposed that in the visual purple there are different kinds of photo-chemical substance, each of which reacts to a different wave-length, thus producing the sensation in the brain of a different color. As to the details of this process, there are many different theories advanced by various scientists.

The Young-Helmholz theory holds that there are three such substances, reacting to wave-lengths which produce the sensations of red, green and blue, respectively. If either one of

these three substances be stimulated alone, it produces the single sensation of red, or green, or blue, as the case may be. If two are stimulated at the same time, a sensation is produced of a mixed color—e. g., if red and blue are stimulated together the resulting sensation is purple. In fact, all other color sensations are produced by mixed stimulation of two or more of the substances, in varying degrees of intensity, just like the mixing of paints together in varying proportions. Equal stimulation of all three gives the sensation of white light.

Another theory, the Hering theory, also assumes three different photo-chemical substances, but ascribes to each a two-fold action, namely, a decomposition or tearing-down under the influence of certain wave-lengths, and a synthesis or build-up under the influence of certain other wave-lengths; known as catabolic and anabolic actions, respectively. Both the tearing-down and the building-up of each of the three substances give different color sensations. The double sensations thus ascribed to the three substances are as follows: White-Black; Red-Green; Yellow-Blue.

Other color sensations, under the Hering, as under the Young-Helmholz theory, are due to mixed stimulations.

The three color sensations produced by single stimulation under the Young-Helmholz theory, and the six predicated by Hering, are known as primary colors. (See **Color.**)

COMPLEMENTARY COLORS.

If the eye gazes for several moments steadily upon a single, or primary color, and then it be either closed or else fixed upon an area of neutral tint, an area of another color will be seen, similar in size and shape to that of the primary color originally gazed upon. Thus, if one first look at an area of red, the after-color will be green; if blue, then the after-color is yellow. These colors are said to be complementary of each other.

Young and Helmholz explain complementary, or rather after-colors, on the ground that after gazing for a while at the primary color the photo-chemical substances in the retina corresponding to that color become exha[illegible]nable to function; so that when the gaz[illegible] or

neutral area, where all the three color-waves are stimulating the retina, only the other two substances respond, and the resulting sensation is a mixture of the other two primary colors. Thus, if we look steadily at red, the red substance is exhausted, and when we turn to a neutral area only the green and blue substances respond, giving the sensation of a bluish green. When blue is gazed at first, then the red and green form the after-color, giving a sensation of reddish yellow. It was a study of complementary colors that led Young and Helmholz to formulate their theory of color sensations.

Hering explains after-colors on the ground that they represent the tearing down and the building up of the same photo-chemical substances, which, of course, naturally follow each other. So, if we look steadily at red, our red-green substance is being torn down; turning to a neutral area, this substance now begins to build itself up, and in so doing gives us the sensation of green. If we first look at green, the substance is being built up, and when we turn to a neutral area it begins to be torn down, giving the sensation of red. And so with all the photo-chemical substances.

It may be said, in passing, that there are many facts and phenomena in regard to color which cannot be explained on either of these two theories, and some which seem to be inconsistent with both of them. We must, therefore, conclude that no satisfactory theory has yet been formulated to account fully for all the phenomena. The field presents opportunities for interesting investigation.

COLOR BLINDNESS.

Some persons are physiologically incapable of distinguishing certain colors; a few, indeed, are unable to distinguish color at all and live all their lives in a world of black-and-white, but they are very rare. Such a condition is known as color blindness, partial or complete. It is generally supposed to be due to the lack in the retina of those chemical substances which react to the stimulation of the wave-lengths of the color, or colors, to which they are blind.

According to the theories of both Young-Helmholz and Hering, we should naturally expect to find a person who is

blind to one of the primary colors also blind to its complementary color; and, in general, this is what we find in actual practice. The commonest color-blindness is for red and green. However, there are here and there persons met with who appear to be blind to one of these two colors and not to the other—which is rather upsetting to both theories. It is one of the things not yet satisfactorily accounted for.

IN INDUSTRIAL PURSUITS.

In certain industrial pursuits, notably in railroad work, where colors are used for signalling, the detection of color blindness is highly important, to avoid accidents. Unfortunately, red and green, to which most color-blind persons are blind, are the two colors most used for signal purposes, because they carry the farthest and through the worst weather, and also because, being complementary colors, they are most easily distinguished from each other.

The color-blind person sees mixed colors without the admixture of the particular color to which he is blind. Thus, if we show a person who is red-blind a purple color, which is a mixture of red and blue, he does not see the red in it, but only the blue; to him it appears blue. If we show him an orange, which is a mixture of red and yellow, he sees only the yellow. If we show him a mixture of many colors, containing his blind-color, but none of them in great saturation, he sees them as a greyish hue. These are called his confusion colors; and we make use of them to test his color sense or blindness. All tests for color blindness are based on this principle.

Different colored surfaces, when polished, have characteristic glares, which a color-blind person is sometimes able to differentiate from each other, and thus to pick out colors to which he is blind. To obviate this, Holmgren devised the plan of making the test with colored skeins of wool, upon which there is no glare, but a dead, saturated color. Eldridge-Green, of London, has devised a set of tests with lanterns, on the ground that the industrial use of colors is usually in the form of transmitted lights; and this test has now become fairly standard with English railroads. This scientist has also worked out a distinctive theory of color perception in general, which, however, is too extensive to go into here.

Pigment. Coloring matter in the tissues.

Pigmentum Nigrum. The black pigment in the choroid.

Pilc Reflex. Contraction of the pupil on having the attention suddenly called to an object.

Pilocarpine. An alkaloid of jaborandi, used in the eye as a myotic, to contract the pupil and reduce intra-ocular pressure. It is not quite so powerful or so irritating as eserine, and is therefore often used in place of that drug. It is employed in aqueous solution of from one-half to four per cent.

Pince-Nez. A term for nose-glasses.

Pinguecula. A small yellowish elevation at the limbus, seen in old people.

Pin-Hole Disc. An opaque disc, with a pinhole in the center. When mounted before the eye, this disc cuts out all but the central rays of light, which, traveling along or near the principal axis, are practically uninfluenced by the refraction of the eye. Where the eye has poor vision, therefore, this disc furnishes a test as to whether the trouble is due to refractive error or to disease. If to the former, the pin-hole, by eliminating the peripheral, refracted rays, does away with the effects of the error, and makes vision better. If to the latter, it does not improve, but rather makes vision worse, by shutting out light from a disabled retina. The general rule is that if the

Pin-Hole Disc.

pinhole disc improves vision, a lens can be found which will improve it. The rule must not, however, be taken too absolutely.

Pin-Hole Image. An image made on a screen by means of interposing an opaque screen with a pin-hole in it between the object and the image-screen. There are a certain number of rays from every point on the central portion of the object which pass as principal rays through the pin-hole, and, falling on the screen, define an inverted image. Naturally, it is neither a very clear image nor a very intense one, since it represents only a small proportion of light from the object. It becomes less intense as the receiving-screen is moved further away from the pin-hole, but its clarity is the same wherever the screen is held. It can be made better-defined by refocalizing through a convex lens.

Pin-Hole Test. If an opaque disc with a pin hole in the center be placed before the eye, so that the pin hole coincide with the center of the pupil, then the only light which is admitted to the eye is that which passes along the principal axis, and approximately thereto. As this light undergoes practically no refraction, the images made by it on the retina are not affected by any error of refraction the subject may have; hence, in a patient whose vision is ordinarily affected by an error of refraction, the pin-hole disc will sharpen and clarify the vision. On the other hand, in a patient whose vision is affected because of a retinal disease, the pin hole will make vision still worse, because the central part of the retina suffers most from organic disease.

Pink Eye. A highly contagious form of catarrhal conjunctivitis, in which the eyeball is of a pink color.

Pladarosis. A soft tumor on the eyelid.

Plane. A surface such that if any two points in it are joined by a straight line, that line will lie wholly within the surface.

As applied to mirrors and lenses, the term means that the surface of the mirror or the lens lies in a single plane, i. e., that it has no curvature whatever.

Plane, Principal. A plane dropped from the principal point of a lens perpendicular to its principal axis.

Plano-Concave. Plano on one side and concave on the other.

Plano-Convex. Plano on one side and convex on the other.

Plica. A fold of skin or mucous membrane.

Plica iridis. A fold on the posterior surface of the iris.

Plica semilunaris conjunctivae. A fold of the conjunctiva at the inner canthus.

Points. In every lens there are four points, lying along its principal axis, from which, being known, all the mathematical problems of its action can be calculated. These are known as the cardinal points of the lens, and are as follows:

(1) The first, or anterior, principal focus, i. e., the point anterior to the lens, light-waves proceeding from which are rendered neutral upon entering the lens.

(2) The second, or posterior, principal focus, i. e., the point posterior to the lens at which neutral waves in the lens are brought to a focus on emerging from the posterior surface.

(3) The first, or anterior, principal point, i. e., the point from which to the first principal focus the focal length of the first refracting surface of the lens is measured.

(4) The second, or posterior, principal point, i. e., the point from which to the second principal focus the focal length of the posterior lens surface is measured.

As a matter of fact, the two principal points can no more be regarded separately than the blades of a pair of scissors. They must be considered and defined as a pair. They are the points of separation of the focal systems of the two surfaces by the thickness of the lens.

All four of these points are joint functions of the thickness of the lens, its index of refraction, and the radii of curvature of its two surfaces.

In addition to the four cardinal points, a lens has two nodal points,—points within the lens on the principal axis from which the object and the image appear under the same angle. For further description of these points see **Nodal Points.**

In thin ophthalmic lenses the principal and nodal points are regarded as being identical with the optical center of the lens.

The eye, being a triple compound lens system, has three sets of cardinal and nodal points situated along its principal axis; but for working convenience three systems are calculated as one, the position of the points being averaged as follows:

The principal point, where the imaginary surface of the reduced eye cuts the principal axis, 2.34 mm. behind the anterior surface of the cornea.

The nodal point, .476 mm. in front of the posterior surface of the crystalline lens.

The posterior principal focus, (in the emmetropic eye), where the retina cuts the principal axis.

The anterior principal focus, varying as to its position with the dioptrism of the eye.

Point of Reversal. The point where a minus light wave focusses and reverses itself into a plus wave. In technique this term refers to the focussing and reversing of the emergent wave from the patient's eye in retinoscopy. See **Retinoscopy.**

Pole. Geometrically, this is the name given to either extremity of the diameter or axis of a sphere. In physics, a pole is one of the points of a body at which the attraction or repulsion energy is concentrated, as the poles of a magnetic needle, the poles of a battery, etc.

In optics the word is used geometrically. The poles of a lens are the points where the two surfaces cut the principal axis, i. e., the anterior and posterior poles. The same holds good of the crystalline lens of the eye.

Polarimeter. An instrument for measuring the rotation of polarized light. See **Polarization.**

Polariscope. An optical instrument for exhibiting the polarization of light, or for examining transparent media for the purpose of determining their polarizing power. See **Polarization.**

Polarization. A wave of light, on entering certain crystalline media, can give rise to two refracted pencils, one re-

fracted according to the ordinary laws of refraction, the other according to a law determined by the form and orientation of the surface of the crystal (Huygens' Law). The first is called the ordinary ray, the second the extraordinary ray. In the case of Iceland spar, and several other crystals, the extraordinary ray is refracted away from the axis, but in many cases this is reversed. Crystals of the former kind are called positive, and of the latter kind negative.

Waves that have been extraordinarily refracted acquire certain new properties with respect to transmission through a second crystal, and are said to be polarized. In addition to this process of double refraction, light may be polarized in the following ways:

Reflection at a proper angle (the polarizing angle) from the surfaces of transparent media, as glass, water, etc.

Transmission through a sufficient number of transparent uncrystallized plates at proper angles.

Transmission through a number of other bodies imperfectly crystallized, as agate, mother-of-pearl, etc.

Diffraction through a grating.

Polarized light cannot be distinguished from ordinary light by the naked eye. To demonstrate polarization two pieces of apparatus are necessary, one to polarize the light, the other to show the polarization. The former is called the polarizer, the latter the analyzer. And every apparatus which serves one purpose will serve the other also. The usual process consists in viewing the examined light through the analyzer, and observing whether any change of brightness occurs as the analyzer is rotated. There are two positions, differing by 180 degrees, which give a minimum of brightness; and the two positions intermediate between these give a maximum. The extent of the changes thus observed is a measure of the completeness of polarization.

The practical value of polarized light to the refractionist and other workers in optics is that it is easier to control and is not reflected in a thousand different planes, as ordinary light is. (See **Light.**)

Polychromate. One who is able to distinguish many colors,

Polycoria. More than one pupil.

Polyopia. Multiple vision.

Pop-Eyed. Having protruding eyeballs.

Porus Opticus. The opening through the lamina cribrosa giving passage to the central retinal artery and vein.

Positive. In optics the term refers to geometric points that are actual, and their measurement and relationships. Thus, positive foci are points where light waves are actually brought to a focus.

The word is also loosely used to indicate expanding light waves, and those reflecting and refracting surfaces which produce them. Such waves and surfaces are better termed plus.

Post-Ocular. Situated behind the eyeball.

Post-Ocular Neuritis. Inflammation of that part of the optic nerve posterior to the eyeball. It is more commonly called Retrobulbar Neuritis.

Postopticus. Any one of the nerve centers or sub-centers back of the optic nerve.

Prelachrymal. In front of the lachrymal sac.

Presbyopia. Literally, the sight of old age. The term is used to denote that physiologic state in which, by reason of the hardening of the crystalline lens, the individual is no longer able to accommodate for his convenient near point. To this pass every emmetropic and hyperopic person, and every myope whose myopia is less than 3 D., comes at some time about middle age; and, as a matter of fact, high myopes come to the same pass, but, owing to their static refractive conditions, they need no accommodation for near point, but quite the reverse.

In former days the commencement of presbyopia was arbitrarily fixed at the recession of the near point to 33 cm. The process of lens-hardening, of course, begins quite early in life, and steadily progresses with the years; and with this gradual loss of accommodation the near point gradually recedes further

and further from the eye. When it reached 33 cm., which means that the accommodation dropped to 3 D., presbyopia was said to have begun. This point was generally supposed to be reached at 45 years of age; hence our tables formerly showed 45 years as the age, and 3 D. as the dioptric amplitude, at which presbyopia commenced.

Nowadays, however, we do not attempt to fix either the age or the amplitude at which presbyopia begins. A person becomes presbyopic, as stated at the outset, when his amplitude of accommodation is no longer adequate to negotiate the near point at which he wishes to read, or to do his customary work. The age at which people lose their accommodative power varies greatly; so does the accommodative demand in different individuals. Further, we now know that a certain amount of accommodative reserve is necessary—or at least desirable—for comfortable near vision; so that the exact dioptric value of the amplitude is not a correct measure of presbyopia; and this reserve differs, also, in different persons.

The clinical problems of presbyopia are essentially those of insufficient accommodation. Under our present knowledge of the subject it is no longer permissible to regard, or to treat, presbyopia as an entity; to merely find the point at which the patient reads, divide the distance into unity, and add to the amplitude thus found the dioptres of lens power which will bring it up to the proper figure. It is really better that the term "presbyopia" should be left out of mind altogether, and each individual case thoroughly investigated and handled as a problem in accommodation and in accommodation-convergence relation. For details of such investigation and treatment the reader is referred to the sections on **Accommodation** and **Convergence.**

Primary. As applied to two or more phenomena, or problems, or functions, it refers to the thing-in-chief, of which the other or others are derivatives.

Primary Colors. Colors produced by single stimulation of the photo-chemical substances in the retina.

Primary Deviation. The deviation made by a squinting eye when the sound eye is fixing.

Primary Position. The position of the eyes in convergence from which all others are calculated, i. e., position of rest.

Principal Focus. The point on the principal axis where a spherical mirror or lens brings neutral light waves to a focus.

Principal Meridians. The meridians of greatest and least curvature in an astigmatic eye. (See **Astigmatism.**)

Principal Points. See **Points.**

Prism. A prism may be defined as a homogeneous refracting body having two plane refracting surfaces inclined toward each other. In ophthalmic practice prisms are usually made of crown glass, the same as ophthalmic lenses. In shape, i. e., in the arrangement of its refracting and non-refracting surfaces, a prism may be rectangular, triangular, or circular. Rectangular prisms are used only in experimental optics; for clinical purposes we employ almost exclusively the circular form, because it fits conveniently into the trial frame.

The place where the two refracting surfaces meet each other is called the apex of the prism; the place where the distance between these surfaces is greatest, the base; a perpendicular dropped from the apex to the base is called the apex-base line.

In conformity with the laws of refraction, a wave of light which falls upon the surface of a prism other than perpendicularly to that surface (entering ray) is refracted toward the perpendicular of the surface, i. e., toward the base. It travels unchanged through the prism, and upon emerging at the other surface—provided it emerges other than perpendicularly—is refracted away from the perpendicular, i. e., once again toward the base (emerging ray). The net effect of a prism, therefore, upon the refracted wave, or ray, is to bend it around its base.

MAXIMUM AND MINIMUM POWER.

The degree of bending power thus exercised by a prism varies according to the angle at which the wave enters or emerges from it. Its greatest power is exercised when all the bending is done at one surface, i. e., when the ray either enters or emerges perpendicular to the surface. The ray is bent the least when, upon entering, it is made to pass through the prism

parallel with the base. These constitute, respectively, the maximum and minimum bending power of the prism. Its middle, or medium power is exercised when the ray enters the prism parallel with the base. It is this medium power which we generally invoke in clinical practice.

DEVIATION.

Everything else being equal, the degree of deviation which a prism gives to a ray of light depends upon the angle which the two refracting surfaces make with each other; that is to say, the apex angle; and this angle is therefore known as the angle of refraction. Originally prisms were designated by this angle.

Later, it was demonstrated that the average deviation of a prism, that is to say, the deviation it gives to a ray which enters parallel to the base-line, is equal to about half the apex angle, and this half angle, known as the prism angle, because the unit of designation for prisms. Neither of these two methods of designation was very satisfactory, however, because they represented the physical properties of the prism rather than its actual deviating power.

Dennet was the first to devise a system of numeration for prisms in terms of the deviation which it actually gave to a ray of light. He measured the deviation by the arc subtending the angle of deviation, taking as his unit the one-hundredth part of the radian, which he called a centrad.

Still later, Prentice proposed a method of measuring the deviation by means of a tangent to the arc, perpendicular to the normal ray, from the point where this tangent cuts the normal ray to the point where it cuts the deviated ray. Prentice took for his unit the tangent of deviation thus shown at a distance of 1 meter from the entering surface of the prism, when that deviation measured 1 centimeter. This unit of deviation he called a prism dioptre. This system of numeration, which is now almost universally employed in this country, has three decided advantages:

(1) It affords a ready formula for the calculation of deviating power at any distance by means of a plane screen or chart. If D stands for the distance at which the measurement is made,

d for the amount of deviation in centimeters, and p. d. for the prism dioptres, then:

$$\text{p. d.} = \frac{d}{D}$$

(2) It gives us a system of mensuration and calculation which coincides with the dioptric system of designating lenses —a feature of great practical value in decentration problems.

(3) It permits of the direct practical application of prism measurement to the diagnosis and correction of errors of convergence, with their relations to accommodation.

APPARENT DISPLACEMENT OF IMAGE.

In viewing an object through a prism, the rays of light which reach the eye from the object are bent around the base of the prism; the eye, however, projects the rays back along a straight line continuous with the line which the emergent rays traversed from the prism to the eye; there is, therefore, always an apparent displacement of the image toward the apex of the prism.

PRISMATIC ABERRATION.

Not only is the image of an object apparently displaced by viewing it through a prism, but it is distorted as well. This is due to what is known as prismatic aberration. In addition to the ordinary forms of aberration which the prism shares with all refracting bodies, it possesses a peculiar aberration of its own, due to the fact that no constant ratio exists between the angle of incidence and the angle of refraction, but only between the sines of those angles. All homocentric light, i. e., all light proceeding from or going toward a point, after traversing a prism is no longer homocentric. This brings about a lateral aberration, or astigmatism, which, in the wearing of high-power prisms, gives a great deal of trouble.

DISPERSION.

All prisms possess the property of breaking light up into its component color waves, since the different color-waves are unequally refrangible, and are deflected through different angles. This phenomenon is known as dispersion. The violet rays are deflected the least, and red the most, and the inter-

mediate colors are spread out between these two extremes, forming the spectrum. This property of dispersion is of great value in spectrum analysis, but a serious disadvantage in the ophthalmic use of prisms because of the colored margin it gives to every object in proportion to the strength of the prism used.

Prisms for clinical use are made of crown glass because its dispersive power is much less than that of flint glass, being as 33 to 52. Achromatic prisms can be made by combining these two kinds of glass in proper relationship.

ROTATING PRISMS.

Sir John Herschell first demonstrated that by placing two prisms in apposition and rotating them in opposite directions it was possible to produce the effect of a single increasing or decreasing prism. If two prisms of equal strength be placed, apex to base, they neutralize each other, so that the prism effect is zero. The further they are rotated from this position the greater becomes the prism effect of the combination, until, when they lie apex to apex, the strength of the combination becomes equal to the sum of the two prisms.

This principle underlies the various rotary prisms and phorometers which are on the market, for use in the testing and exercising of the ocular muscles.

CLINICAL USE OF PRISMS.

Since a prism can deflect the path of a light-wave to any given degree, depending upon the size of its apex angle, it is evident that it can make a neutral or infinite wave appear as though it came from a point within infinity, or vice versa; and by placing prisms before the eye we can thus induce an exercise of positive or negative convergence, for the purpose of maintaining single binocular vision, according to the position and strength of the prism. If the prism be placed before the eye with its base toward the temporal side, i. e., "base out," the rays of light will be made more divergent, and the eyes will be obliged to turn inward to maintain single vision. If it be placed "base in" the rays will be made more convergent, and the eyes will have to turn out. By means of numbered prisms, therefore, the internal and external rectus muscles can be forced into action to the limit of their physiological capacity, and that capacity expressed in prism dioptres. With the base

up or down, the same thing can be done in respect of the superior and inferior recti.

Again, in virtue of its deviating power, a prism may be made to diverge or converge the rays of light entering a pair of eyes whose visual axes are in a permanent state of obliquity, as they are in strabismus or manifest heterophoria, so as to equalize and compensate for their obliquity, i. e., so as to coincide with their visual axes; and the numbered strength of the prism which accomplishes this will, of course, express in prism dioptres the degree of imbalance existing.

Again, the same prism deviation which measures ocular imbalance by equalizing the deviation of the visual axes also remedies the condition by enabling the eyes to maintain single binocular vision without exercise of the ocular muscles, and thus serves as a correction.

The above represent the three chief uses of prisms in ophthalmic practice. There are other auxiliary uses. Maddox enumerates seven applications of prisms in clinical work, as follows:

(1) To measure the functional minimum of convergence.
(2) To measure the absolute maximum of convergence.
(3) To measure the relative range of convergence.
(4) To dissociate convergence and accommodation.
(5) To detect vertical deviations.
(6) To measure strabismus.
(7) To determine the presence or absence of binocular vision.
(8) To elicit diplopia in suppression of the false image.
(9) To relieve excess of tonic convergence.
(10) To relieve deficiency of tonic convergence.
(11) To relieve excess of accommodative convergence.
(12) To relieve deficient accommodative convergence.
(13) To correct diplopia in oculo-motor paralysis.
(14) To assist in curing paralytic diplopia.
(15) To disguise the squint in an amblyopic eye.

For detailed particulars of the use of prisms for [illegible] purposes, the reader is referred to the sections on [illegible] **Heterophoria,** and **Strabismus.**

Prism Dioptre. The unit of prism power measurement. One prism dioptre is the power to deviate a ray of light 1 in 100, i. e., 1 cm. in one meter distance. Devised by Chas. Prentice of New York.

Prismoptometer. An instrument for testing the eye muscles with prisms.

Prismosphere. A combined spherical lens and prism.

Projection. Geometrically, this term implies the continuation of a line, or a series of lines, in one direction or the other, under precisely the same spacial conditions that they already exhibit. Thus, if two lines are inclined toward each other at a certain angle of deviation, we can project them in the direction of their inclination to a meeting point, or in the direction of their deviation at the same angular deviation that they already have.

Physiologically, the word signifies the tracing of a sensation by the brain to its point of origin. Strictly speaking, as a matter of pure sense, this projection cannot go beyond the place at which the stimulus entered the body. All so-called projection beyond that point, into space, is not genuine projection at all, but cerebral judgment, arrived at by means of other data than that supplied by the sense itself.

As applied to light and optics, this implies that the brain can project the impression made by light falling on the retina only as far as the cornea. Whatever further projection into space the brain performs, or thinks it performs, is a matter of mental judgment, based upon the size of the image, the use of the accommodation and convergence, and former experiences. It follows, therefore, that beyond the cornea the projection of images can be only in a straight line. No matter where the source of light, i. e., the object, may really be in space, the origin of the impression, so far as the sense of vision is concerned, is at the cornea, where the light first enters the eye. Further projection is a mere continuation of the linear projection from the retina to the cornea.

When, therefore, light waves from an object are made to turn corners or curves before they enter the eye, as in the

case of prisms and mirrors, the sense of vision projects the image back, not to its actual place in space, but in a straight line with the visual axis. The angular separation of the actual object and the projected image is called the angle of false projection.

Pro-Ophthalmos. Bulging of the eyeball forward.

Prothesis Ocularis. The inserting of an artificial eye.

Protractor. A device for centering lenses and prisms. There are several different varieties on the market. Most of them, however, consist essentially of a chart with either radiating or cross lines, which are viewed through the lens or prism; the lens or the chart is made to revolve until the lines are seen unbroken, in the case of cylindrical lenses and prisms; in centering spherical lenses the movement is lateral, until the same thing is attained.

Pseudoblepsia. Perverted vision.

Pseudo-Glioma. A false appearance of glioma, due to a pus sac in the vitreous.

Psorophthalmia. Itchy ulceration of the eyes.

Pterygium. An overgrowth of conjunctival tissue which starts from the inner canthus and creeps over the conjunctiva toward the cornea. Occasionally it encroaches upon the cornea, in which case it interferes with vision and calls for surgical removal.

Ptilosis. Falling out of the eyelashes.

Ptosis. Drooping of the upper eyelid, usually due to paralysis of the third nerve.

Puncta Lacrimalia. The two eminences in the inner part of the eyelids where the tear ducts open into the conjunctiva.

Punktal Lens. A development of the deep curve lenses (Toric and Meniscus), the surfaces of which are curved and are more nearly perpendicular to the line of sight passing through the margin—separate computation for the power of each lens

and its correction must be followed. Each lens is ground and polished according to a formula specially computed for the particular power of the kind of lens.

Punctum. A point.

Punctum Proximum. The near point.

Punctum Remotum. The far point.

Pupil. This name is given to the circular aperture in the diaphragm of the iris. It varies in size continually, enlarging when the iris is drawn back toward its base and becoming smaller when the iris is drawn centripetally in the direction of its free margin. Both dilation and contraction of the pupil are positive muscular phenomena, due, respectively, to the innervation and contraction of the radiating and circular muscles of the iris. (See **Iris.**) The former is innervated through the third cranial nerve (motor oculi), by way of the ciliary ganglion, and the latter through the cervical sympathetics, having their origin in the cervical ganglia anterior to the spinal cord, which tap the ascending sensory paths of the cord.

Because of this double nerve connection of the iris, the size, shape and behavior of the pupil furnish extremely valuable data, in health and disease, as to the state of the body, manifested through the sympathetic and the cerebro-spinal nervous systems, of which only a brief summary can be given here.

In health the shape of the pupil is almost perfectly circular. Distortions are practically always due to local, mechanical causes—the dragging of the iris in one or more directions, either by reason of its being stuck down to the iris or the cornea by exudates, or being caught in a wound of the cornea or limbus. The former accident occurs in iritis and other inflammatory diseases of the eye; the latter as a complication of operations.

The size of the pupil in health is a difficult thing to specify, because, as stated, it is continually varying under physiological stimuli. What may be called its absolute or constant is personal idiosyncrasy. Since light, which is the principal agent of stimulus for contraction, is a more or less constant factor, i. e., the same for all individuals, it is to the action of the sympathetics, or dilators, that we must look for an explanation

of individual variations in the size of the pupils. In general it may be said that sensitive, neurotic persons, whose sympathetics are easily excited, and react readily, have larger pupils than more phlegmatic individuals.

Much more important are the variations in the size of the pupils due to abnormal or pathological causes, concerning which the following general rules may be laid down:

Mydriasis (dilation of the pupil) is caused by any condition which (a) paralyzes either central or peripheral ending of the third nerve, or the short ciliaries, (b) inhibits the functionation of the third nerve through the brain, or (c) stimulates the sympathetics.

Tumors of the brain, or along the third nerve, toxines of acute infectious diseases (diphtheria, scarlatina, etc.) and the action of certain drugs, notably atropine, are examples of the first class. Fevers, comatose conditions, and excited states of the brain are instances of the second class. Pain, sensory irritation and abdominal diseases furnish illustrations of the third variety.

Myosis (contraction of the pupil), on the other hand, results from influences which (a) irritate the third nerve, or (b) depress the sympathetics.

Photophobia, from whatever cause, meningitis, and certain drugs, such as eserine and pilocarpine, are instances of the former; spinal diseases, aneurisms (by pressure on the nerves), and opium of the latter.

Normally, the two pupils are equal in size. Inequality is practically always due to interruption of the motor-oculi nerve path, either central or peripheral. Central causes are brain tumors, syphilis, tubercle of the brain, and the like. Peripheral causes are injuries to the eye and toxines from acute infectious diseases. Occasionally one pupil is dilated because of pressure on the cervical sympathetics by an aneurism. Diseases which interfere with light stimulus of the retina (cataract, optic atrophy, etc.) will also produce unilateral dilatation.

In health the pupil reacts with great quickness and sensitiveness to stimulus on both sides of the nervous circuit, i. e. to light and to sensory stimulus. A sluggish or immobile pupil may be due to adhesion of the iris to the lens or cornea, or to

paralysis of the third nerve, central or peripheral. Most of the latter class of cases result from syphilis.

The Argyll Robertson pupil, in which the pupil fails to contract in response to light but contracts upon accommodation, occurs in locomotor ataxia, supposed to be due to involvement of Meinert's fibres.

Wernicke pupillary reaction is a test for determining the location of a lesion in the optic tract, employed in cases of hemianopsia. If the light reflex is present in the blind half of the eye then the lesion is back of the optic thalamus; if not, it is in front of this ganglion; because at that point the reflex and optic paths part company.

Hippus, a periodic contraction and dilatation of the pupil, is seen in psychic diseases, mania, hysteria, etc.

In all tests designed to ascertain the reaction of the pupil careful attention must be paid to the presence or absence of light, according as the examiner wishes light to be a factor in the test or not.

Pupillometer. An instrument for measuring the diameter of the pupil. There are many such devices. Edgar Browne's consists of a series of graduated circular holes in an oblong piece of wood or ivory, each one notated with its diametrical measurement; the hole coinciding with the pupillary aperture is easily found. Lawrence's instrument is a screw-sliding bar, much after the fashion of a universal monkey-wrench, which is opened by a screw-movement to the width of the pupil. Priestley Smith's device is an opaque disc, with a graduated slit in it.

Pupilloscope. Pupilloscopy. An instrument and method for measuring the pupillo-motor sensibility of the retina to light.

Pupillostatometer. An instrument for measuring the distance between the pupils.

Purple, Visual. The reddish photo-chemical substance in the rods of the retina, the disintegration of which constitutes the physical stimulus of vision.

Pyophthalmia. Pus in the eye.

Quadrant. The section of a circle containing one right angle.

Quadrigeminal Bodies. A group of four nerve ganglia at the mid-brain, composing a portion of the sub-station generally known as the optic thalamus, where the neurons from the optic tract are relayed. See **Optic Tract** and **Physiology of Vision.**

Radial. Diverging, as rays, from a centre.

Radian. An arc of a circle equal to the radius. A hundredth part of the radian is a centrad, one of the units of measurement of the deviating power of a prism. See **Prism.**

Radiant Energy. A form of energy which is propagated through the medium of the luminiferous ether, of which light is a conspicuous example.

Radiation. Divergence, in the form of rays, from a centre.

Range of Accommodation. The distance between the far point and near point of accommodation. See **Accommodation.**

Range of Convergence. The distance between the far point and the near point of convergence. See **Convergence.**

Ray. The geometrical equivalent of a wave of light, showing its linear propagation. When we wish to work out linear calculations, we use the ray. When we are working with curvatures, we use the wave. Both, of course, are mere symbols.

Rectangle. A four-sided geometrical figure, having all its angles right angles, and therefore its opposite sides equal and parallel. A rectangle is said to be contained by any two of its sides containing one of its right angles.

Rectus. Literally, straight. Applied to all those muscles of the eye which move the eyeball in a direction straight with the vertical or the horizontal meridian. See **Muscles.**

Red-Blindness. Inability to distinguish red color. It is the commonest form of color-blindness.

Reduced Eye. The refractive system of the eye based upon an imaginary surface having the same net dioptrism and the same

posterior principal focus as the compound refracting system of the eye. (See **Eye**).

Reflection. The turning back of a wave of light by a more or less polished surface. Reflection occurs in accordance with two laws, namely,

1. The angles which the incident and reflected rays make, respectively, with the perpendicular of the reflecting surface, are equal.

2. The incident and reflected rays are in the same plane.

For practical aspects of reflection see **Mirror.**

Reflector. A device for reflecting light, usually consisting of a polished curved surface.

Reflex. In physiology a reflex is an automatic, or unconscious, response of a muscle to stimulus, mediated through the nervous system. The necessary factors to a reflex are (1) a stimulus, (2) a sensory nerve path to the cord or brain, (3) an arc, where the nerve impulse is transferred from the sensory to a motor nerve path, (4) a motor nerve path, to carry the responding impulse to a muscle, and (5) a muscle, to contract in response to the stimulus.

In the case of the eyes there are two important reflexes, which ought to be thoroughly understood by those who deal with them:

(1) The light reflex. This is the response of the concentric muscles of the iris to the stimulus of light, causing the pupil to contract when light is thrown upon the retina. In this instance, the stimulus is the light, the sensory nerve path is the optic tract (q. v.) as far back as the quadrigeminal bodies, the arc is the optic thalamus, the motor path is the third nerve, and the muscle the concentric or sphinctre muscle of the iris. Any interruption to this round-trip nerve course will interfere with the integrity of the light reflex.

(2) The accommodation reflex. This is the response of the ciliary and sphinctre iridis muscles to the call for a clear image. Here the stimulus is an indistinct image, i. e. a confusion circle of unfocussed waves, falling upon the retina, the sensory path is the entire optic tract (q. v.) clear to the left frontal convolution of the brain, the arc is in the frontal convolution, the

motor path is from the frontal lobe to the fourth ventricle and thence along the third nerve to the ciliary ganglion, thence by sympathetics to the ciliary body, and the muscles are the ciliary and the sphinctre iridis. Any interruption of this course, at any point, will interfere with the accommodation reflex.

The light reflex is impaired or destroyed in certain well-known diseases of the nervous system, such as locomotor ataxia, myelitis, spinal syphilis, etc. The accommodation is rarely interrupted.

When we put atropine, homatropine, or cocaine in the eye, we arbitrarily interrupt both light and accommodation reflexes, by temporarily paralyzing the endings of the motor nerve path which conduct the impulse to the ciliary and iris muscles.

When we put eserine or pilocarpine in the eye, we artificially imitate these reflexes by keeping up an irritation of the endings of the motor nerve tracts.

In either of the above reflexes, if the stimulus be applied to one retina alone, the other eye will respond. This is known as the consensual reflex. (See **Physiology of Vision**).

Refracting Media. Any bodies or substances through which light passes and is refracted as it passes. The refracting media of the eye are the cornea, the aqueous humor, the crystalline lens, and the vitreous.

Refraction. When a wave of light, moving in a given medium, falls upon the surface of another medium of different density, if the normal of the wave-curve is perpendicular to the surface, it passes through the new medium unchanged; but if the normal of the wave-curve be other than perpendicular to the surface, its curvature is changed as it enters the new medium, and the direction of its rays altered. If the waves pass from a rarer into a denser medium, the rays are bent toward the perpendicular of the surface; if from a denser into a rarer, away from the perpendicular. This phenomenon is known as refraction.

The laws governing refraction are as follows:

(1) Incident and refracted rays are in the same plane with the normal at the point of incidence.

(2) The ratio of the sines of the angles between the normal and the incident and refracted rays, respectively, is constant for the two media, varying according to the wave-length of the light. This constant is the relative index of refraction of the second medium. When the first medium is a vacuum, the refractive index is absolute. The refractive index of air is regarded as 1.

The alteration of the wave depends upon the difference of velocity with which it is propagated through the new medium. Light waves travel in air at the rate of approximately 186,000 miles per second; in crown glass their velocity is reduced to slightly over 122,000 miles per second. With the refractive index of air expressed as 1, this makes the refractive index of crown glass a little over 1.50, and this ratio is geometrically expressed by the ratio of the sines of the two angles as stated above.

The change is due to a turning of the wave-front, which, in turn, is due to an interruption of the time rhythm in the propagation of the lateral elements of the wave. If the normal of the wave-curve strikes the refracting surface perpendicularly, this interruption takes place symmetrically on both sides of the normal, so that no turning of the front occurs; but if obliquely, the interruption is asymmetrical, and the front is turned, much as the front of a company of marching soldiers would be turned by crossing a river obliquely.

The degree of refraction, therefore, depends upon the degree of difference in the densities of the two media, and the obliquity with which the normal of the waves strikes the surface.

For practical considerations, see **Lens.** Also **Light.**

Refractionist. One who is skilled in measuring and correcting errors of refraction of the eye.

Refractive. Pertaining to refraction.

Refractometer. An instrument for measuring refraction.

Relative Index of Refraction. The ratio of optical density borne by one substance toward another substance whose density is expressed by a positive number, i. e. other than a vacuum. As compared with a vacuum, the index is said to be absolute.

Reposition. Putting back into the normal place—specifically applied to the replacing of the iris in cataract operations.

Retina. The so-called third tunic of the eye (although histologically it is the first)—a thin, transparent membrane, which is spread out over the inner surface of the chorioid and serves as the sensitive film for the camera of the eye. It consists in reality of a flared continuation of the optic nerve, whose endings are distributed over the retina in the form of rods and cones. The retina is well supplied with blood through branches of the central retinal artery, which enters with the optic nerve.

A little to the temporal side of the optic disc is a small circular area, devoid of vessels, but thickly furnished with nerve endings, which is the most sensitive spot in the retina. Because of its yellow appearance (due to the choroid showing through) it is known as the yellow spot, or macula lutea. In the centre of the macula is a still more sensitive depression, called the fovea centralis.

The retina is made up of ten layers, from within outward as follows:

Internal limiting membrane
Fibrous layer (nerve fibres)
Vesicular layer (nerve cells)
Inner molecular layer
Inner nuclear layer
Outer molecular layer
Outer nuclear layer
External limiting membrane
Layer of rods and cones (Jacobs' membrane)
Pigmentary layer

The layer of rods and cones is the important layer from an optical standpoint, for it is here that the light vibrations are transformed into visual impulses. The rods contain a photochemical substance, known as the visual purple, which gives to the retina in life a reddish color. A few of the cones contain visual purple, but in general they are devoid of it. This substance is decomposed ("bleached") by light waves, each different color wave having a different bleaching power, set-

ting up a visual impulse in the nerve ending. In the macula there are no rods, but only cones, and there is no visual purple.

The retina is attached to the chorioid only at the anterior border (ora serrata) and at the optic disc. Occasionally it becomes partially detached.

Retinal Reflex. The glare of red light produced by the light which emerges from the patient's eye in retinoscopy. Also known as the pupillary reflex.

Retinitis. Inflammation of the retina, characterized by excessive redness and increase in number of visible vessels, and sometimes tiny hemorrhages. There is usually interference with vision. The differentiation between the various types of retinitis and their significance belong to medicine.

Retinoscope. An instrument constructed on the same principle as the ophthalmoscope (See **Ophthalmoscope**), except that it usually is made with a plane reflecting mirror, or, if concave, not so concave as that of the latter instrument. Its object is not to examine the details of the fundus, but to obtain a fair general illumination of the pupillary area.

For use of the instrument see **Retinoscopy.**

RETINOSCOPE.

Retinoscopy. An objective method—in fact, the only available objective method—of determining the refraction of the eye by certain shadow phenomena produced, observed and

modified by means of an instrument called the retinoscope. The procedure is also known as skiascopy, and the instrument as a skiascope.

THE RETINOSCOPE.

The retinoscope itself is an adaptation of the principle of the ophthalmoscope to skiascopy. The ophthalmoscope was the original instrument, designed by Helmholz, as elsewhere related, for the purpose of enabling us to view and examine the patient's retina, by intercepting the light-waves that emerge from the patient's pupillary opening and causing them to enter our own pupil. It was not until several years later that the shadow test for refraction was discovered, and the same principle applied, in a modified form, to this procedure.

The retinoscope, then, consists simply of a small circular mirror, pierced through the centre with a sight-hole, and mounted on a stem handle. The diameter of the mirror is variable, according to the taste and usage of the operator, ranging from 1.5 to 3 cm.; the diameter of the sight-hole also varies from 1 to 2 mm. The mirror may, also, be either plane or concave; although they are never made as concave as an ophthalmoscope mirror, because the same concentration of light is not desired. The plane mirror is most commonly employed, and will be assumed in the following description of retinoscopy.

By means of this circular mirror, light is thrown by reflection from some source of illumination into the patient's pupil and onto his retina. The source of light may be any form of lamp—gas, electric, or even oil—but should be so arranged as to have the examining room in as nearly total darkness as possible. Directions for carrying out this technique will be given later on. Modern retinoscopes are made with their own electric lamps attached to the handle-stem close to the mirror —self-illuminating retinoscopes—and these are much the best to use.

The light being thus thrown by reflection onto the patient's retina, emerges again from the patient's eye through his pupillary opening. It was formerly taught that the light was re-reflected by the retina; and we still speak of the appearance

of the emergent light as the "pupillary reflex." It is now pretty generally considered, however, that the patient's retina itself becomes a source of illumination; and the emergent light is regarded as originating in the patient's retina.

If the retinoscope now be held as nearly as possible in a horizontal plane with the patient's pupil, and not too far away, and the operator's eye be applied to the sight-hole at the back of the mirror, (taking care to keep the reflected light thrown into the patient's pupil), the operator's eye, behind the peep-hole, will intercept the light emerging from the patient's eye, and obtain a view of his retina. It will not be a detailed view; the concentration of light, and the optical relations of the instrument, do not afford a detailed view of the fundus, nor is such a view desirable. It is seen merely as a red glare; technically known as the red reflex.

Considerable practice is needed to be able to execute the manoeuvers necessary to obtaining a good "reflex." And not until this has become easy to the operator can he devote the requisite attention to producing and interpreting the shadow phenomena which constitute the essence of retinoscopy. At the end of this section will be found a set of instructions and suggestions for carrying out the technique of the test, to which the reader is referred.

THE MECHANICS OF THE RETINOSCOPE.

Before proceeding to discuss the principles and technique of retinoscopy, it is important that the student should get a clear conception of the working mechanics of the retinoscope. We have already described the instrument itself; and shown how it enables us to view the light which comes from the patient's retina. It now behooves us to ask ourselves, concerning the use of the instrument in retinoscopy, what it is expected to do, and how it is expected to do it.

Suppose yourself to be standing in the middle of a circular turret, totally dark except for one small round port-hole cut in the wall. This port-hole appears as a small round disc of light. And suppose that, while you are gazing at the port-hole, the whole turret starts to revolve, turning you with it. What happens to the disc of light?

As the turret revolves, a crescent-shaped shadow seems to move across the disc from the side, and in the direction that the turret is revolved. The shadow, or dark area, is in reality the round edge of the wall around the port-hole that has come between your eye and a portion of the light; but as you cannot distinguish the wall, it appears only as a shadow moving across the disc. Or it would be just as correct to say that the disc of light itself is moving in the same direction as the revolution of the turret; but it appears to remain stationary while the dark area following it seems to move.

Suppose, now, that you see this same thing happen, but that your back is turned to the port-hole, and you witness the affair in a mirror. Then the shadow will seem to move across the disc in the opposite direction. Everything is really happening in all respects as before, but the effect of the reflection in the mirror is to reverse, laterally, the light rays that reach you from the disc, and make it appear that the movements are reversed.

Suppose, once more, that instead of being in the middle of the room, watching the port-hole, your face is right at the external opening of the port-hole itself. Then, no matter if the turret revolves on its pivot, in either direction, your view of the light is uninterrupted, and you hardly know the tower is turning.

This illustrates, in a rough fashion, something of the mechanical state of affairs when the pupillo-retinal area of light is viewed through the retinoscope, and the instrument is rotated for skiascopic purposes.

If the pencil of light rays which emerge from the patient's eye and stream through the sight-hole of the retinoscope are as yet unfocussed, (either divergent or parallel), as long as the instrument is held still, in a right plane between the operator's eye and the patient's, the pupil will be seen as a circular disc of red light; but on turning the retinoscope and the operator's head with it, swivel-fashion, the oblique tilt of the mirror outward will cut off some of the rays on that side from entering the operator's eye, and a shadow will seem to move across the pupil from that side.

If the pencil of emergent rays have already focussed before they reach the retinoscope, then the rays which come through the sight-hole will be reversed not, as in the turret illustration, laterally reversed by reflection, but totally reversed by refraction. The result is that, although precisely the same thing happens on rotating the instrument as happened in the previous instance, the shadow will appear to come from the opposite side of the pupil, and move across the pupil in the opposite direction.

As a matter of fact, there is no shadow in the eye, or even on the cornea, in either case; it is that the oblique tilt of the mirror toward the path of the emergent rays prevents some of them from being intercepted by the operator's eye. The illumined area simply goes out of vision on that side. The fact that you can still see the patient's cornea and iris in the area of shadow (just as you can see the rest of his face) is merely due to the general illumination in the room, which cannot be quite prevented. You cannot see the retina in the darkened area.

Finally, if the emergent rays passing through the sight-hole are exactly focussed at the sight-hole, (or, what is practically the same thing, at or near the operator's nodal point), then they are a group of radial points, and a slight rotation of the mirror will not cut any of them off from the observer's eye. We are then, so to speak, in the position of having our faces at the outer opening of the turret port-hole. Whichever way we rotate the mirror, there will be no shadow moving across the pupil.

In the first of these three events the shadow is technically said to move "with the mirror" (i. e. with the retinoscope); and in the second case, "against the mirror." In the last instance, the focal point at the sight-hole of the mirror is said to be the "point of reversal," because if the instrument be held a little within this point (i. e. a little nearer to the patient's eye), there will be a shadow moving "with," and if it be held a little outside this point, (i. e. a little further from the patient's eye), there will be a shadow moving "against." In fact, if there be any doubt in the operator's mind as to whether he has

obtained the point of reversal or not, it is a good idea to test it in this way.

CHARACTER OF THE SHADOWS.

If we consider the emergent rays, treated with the objective lens, as a cone of light, whose base is the pupillary area and whose apex is the point of reversal, then the nearer we get to the apex of the cone the smaller is the cross-section area into which the rays are packed, and the more of these rays will be intercepted by a given depth of cut-off.

In high errors of refraction the point of reversal is relatively far from the mirror of the retinoscope; in low errors it is relatively close to it. In high errors, therefore, the cut-off of the edge of the sight-hole intercepts a relatively small number of the emergent rays, while in low errors the same cut-off intercepts relatively many of these rays. As a consequence, in high errors the pupillary shadows are indistinct, and appear to move slowly; in low errors they are sharply defined, and seem to move rapidly. The nearer we approach correction, the sharper the shadows become and the more rapidly they seem to move.

PRINCIPLES AND PRACTICE OF RETINOSCOPY.

The principle of retinoscopy is the principle of conjugate foci. In any lens system the image-point is conjugate with the object-point, and the two points are relationally interchangeable. In the eye at rest, the retina is conjugate with its far point; and, if the eye be emmetropic, so that its retina lies in the plane of its posterior principal focus, it is conjugate with infinity. Per contra, if the retina of the emmetropic eye be the source of light, the emergent waves will be neutral (infinite) waves.

If an eye be hyperopic, then the retina of that eye at rest is conjugate with a point beyond infinity, and emergent waves are divergent (positive) waves to the extent that the eye is hyperopic. If, on the other hand, the eye is myopic, its retina is conjugate with a point within infinity, and the emergent waves are convergent (negative) to the extent of the myopia.

If, then, some means can be applied to determine whether the emergent waves from the static eye are neutral, positive or negative, and to measure the degree of their divergence or convergence, we can thereby determine, and measure, and cor-

rect the refraction of the eye. Retinoscopy furnishes us the means.

We place before the patient's eye a convex lens of known focal power, say a 2 D., directing him to look into infinity. The focal length of this lens is 50 cm., hence if the waves emerging from his eye are neutral they will be brought to a focus at a point 50 cm. in front of the lens. If, then, we hold the sight-hole of the retinoscope at this point and look through it, we shall see a focussed image of the retina, and whichever way we slightly twirl the mirror we shall continue to see the circular glare of the pupil—there will be no moving shadow.

Assume, now, that the eye is hyperopic, so that the emergent waves, instead of being neutral, are divergent. Then the 2 D. convex lens will not be sufficient to focus these waves at its focal length of 50 cm., and if we hold the mirror at this distance the light which enters the sight-hole, instead of being a group of focal points, will be a group of diffusion circles of unfocussed waves. As long as we look straight through the sight-hole we shall see the circular image of the retina—not clear and bright, as in the case of the focussed image, but blurred to a dull red—but the slightest rotation of the mirror in either direction will produce a shadow moving "with the mirror."

If we now find a plus lens which, added to the 2 D. already before the eye, will serve to just bring the emergent waves to a focus at the 50 cm. point, the shadow will no longer appear, for we shall again be viewing a focussed image of the retina. (Incidentally, the appearance of the image will also become bright yellow-red). This is technically called "abolishing, or neutralizing the shadow." The additional plus lens by which it was accomplished manifestly neutralized the divergence of the emergent waves and rendered them neutral, thus enabling the 2 D. objective lens to focus them at its posterior principal focus. This additional lens (known as the neutralizing lens) is therefore the measure of the patient's hyperopia, and its correction.

Again, assume that the eye is myopic, so that the emergent waves, instead of being neutral, are convergent. In this case the 2 D. convex lens will focus these waves in a less distance than 50 cm., so that if we hold our retinoscope at the 50 cm.

distance the light that enters the sight-hole will be a group of diffusion circles of reversed waves. Rotation of the mirror will in this case produce a shadow moving "against the mirror."

We may proceed to find a concave or minus lens which, when added to the objective of 2 D. already before the eye, will delay the focussing of the emergent waves just sufficiently to make them focus at 50 cm. and abolish the shadow. It is evident that this minus lens exactly neutralized the convergence of the emergent waves and rendered them neutral, so that th 2 D. objective lens was able to focus them at its posterior principal focus. This minus lens, therefore, is the measure of the patient's myopia, and its correction.

Summarizing, then, the general rationale of retinoscopy may be briefly expressed as follows:

1. We seek to determine whether the emergent waves from the static eye are neutral, positive or negative.

2. For this purpose we proceed to force these waves, by means of lens power, to focus at a given distance from the eye,—in other words, to establish an arbitrary conjugate focus with the patient's retina,—and from the amount of lens power needed to do this we calculate the curvature of the emergent waves.

3. The amount of positive or negative curvature thus demonstrated in the emergent waves represents, respectively, hyperopia or myopia.

The method for carrying out the procedure may be summarized as follows:

1. We place before the patient's static eye a convex lens of known dioptrism, and work with our retinoscope at the principal focal point of this lens.

2. If on rotating the mirror no shadow is seen moving across the patient's pupil, his retina is conjugate with the retinoscope; the emergent waves are neutral; the eye is emmetropic.

3. If there appears a shadow moving "with" the mirror, the patient's retina is conjugate with a point beyond the retinoscope; the emergent waves are divergent; the eye is hyperopic. The additional convex lens which makes the retina conjugate with the mirror, and abolishes the shadow, is the measure of the hyperopia.

4. If a shadow is seen moving against the mirror, the conjugate focus is between the retinoscope and the patient's eye; the emergent waves are convergent; the eye is myopic. The additional concave lens which makes the retina conjugate with the mirror, and abolishes the shadow, is the measure of the myopia.

The above-described technique is probably the simplest, as it is the most commonly used. It has two practical advantages: (1) the least degree of hyperopia or myopia is at once apparent in the existence and movement of a shadow, (2) when the point of reversal is obtained, no calculations have to be made, the neutralizing lens representing the error.

There are, however, other methods of procedure for those who prefer them, both with and without an objective lens. Some operators prefer to employ an objective lens only. By this method, instead of forcing the point of reversal on to the mirror, the operator takes his mirror in search of the point of reversal, and having found it, calculates the refractive error by the difference between where the point of reversal ought to be and where it is. If p represents the proper point of reversal, and p^1 the point of reversal as found, then,

$$\frac{1}{p} - \frac{1}{p^1} = \text{error}$$

Thus, if with a plus 2 D. lens before the eye the point of reversal is found at 50 cm. the eye is emmetropic, because the point ought to be at 50 cm., so that we have

$$\frac{1}{.50} - \frac{1}{.50} = 0$$

But if, with this objective, the point of reversal is found at 1 meter, then,

$$\frac{1}{.50} - \frac{1}{1} = 1 \text{ D.}$$

The eye is 1 D. hyperopic. Or if, with the same lens, the point of reversal is found at 25 cm., then,

$$\frac{1}{.50} - \frac{1}{.25} = -2 \text{ D.}$$

The eye is myopic 2 D.

This method also has its elements of technical simplicity, chief of which is that the operator does not have to keep changing lenses. Having placed the objective lens, he begins at some convenient distance—say a meter, to shadow the eye. If he happens immediately to find the point of reversal (no shadow), all that remains is to make the calculation. If he finds a shadow moving with the mirror, he changes the objective lens for a stronger one, until the shadow moves against the mirror. Then he moves his mirror gradually in toward the patient's eye until he finds the point of reversal, measures the distance from the patient's eye, and makes his calculation against the focal length of the objective lens, as shown above.

Still another method is to work at a fixed distance, without an objective lens at all, but only a neutralizing lens. In this case, the operator simply finds the lens which will abolish the shadow by bringing the point of reversal on to his mirror. If, when he starts to shadow, the shadow is moving with the mirror, it will require a convex lens to neutralize; if it is moving against it will require a concave lens. Having neutralized the shadow, he then subtracts from the neutralizing lens the reciprocal of the distance at which he worked—called the working distance equivalent—and the remainder represents the refractive error.

Thus, if the operator works at 50 cm., and finds the shadow moving with the mirror, and it requires a plus 3 D. to neutralize the shadow, then,

$$3 - \frac{1}{.50} = 1 \text{ D.}$$

The eye is 1 D. hyperopic. Or if, working at the same distance, the shadow is seen to move against the mirror, and it takes a minus 2 D. to abolish the shadow, then,

$$-3 - \frac{1}{.50} = -5 \text{ D.}$$

The eye is 5 D. myopic. Or, again, if, at the same distance, the shadow is seen to move with, and it takes a plus 1 D. to abolish the shadow, then,

$$1 - \frac{1}{.50} = -1 \text{ D.}$$

The eye is 1 D. myopic.

As will be seen, this method really amounts, in the last analysis, to the same thing as the method first described, the objective power being figured in with the neutralizing power and then figured out again, instead of being placed before the eye in the form of a lens at the outset, and never figured into the neutralizing power.

RETINOSCOPY IN ASTIGMATISM.

In applying retinoscopy to the detection and estimation of astigmatism, we have only to bear in mind that it is still a question of conjugate foci, and that we are dealing with the same focal conditions on the anterior side of the ocular lens system that exist on the posterior side. In the definition and description of astigmatism, it is shown that the two chief meridians of the eye have different refracting power, and therefore two posterior principal foci, both situated on the principal axis, one more posterior than the other—or one more anterior than the other, it makes no difference how we state it. Precisely the same thing is true of the anterior focal relations of an astigmatic eye—its two chief meridians have two different anterior principal foci, two different sets of conjugate foci, and therefore two points of reversal, one more anterior than the other.

In shadowing an astigmatic eye, then, we have to shadow two different ocular lens systems, corresponding to the two chief meridians, involving two complete operations by any one of the methods already described; determine the refraction of each meridian separately; and calculate the astigmatism by the difference between the two refractions.

The general rule of procedure is very simple. In the case of a non-astigmatic, spherical eye it is immaterial, of course, in which meridianal direction we rotate the mirror, since the curvature of the eye is the same in all of its meridians, and the shadow, if there be one, will behave the same in every meridian. In the case of an astigmatic eye, we have to ascertain the axes of the chief meridians, and do our shadowing,

i. e., rotate our mirror, at right angles to these two meridians, where the directions of greatest and least refraction lie.

DETERMINING THE CHIEF MERIDIANS.

The crux of the problem is the determination of the axes of the two chief meridians. Fortunately, this is not, as a rule, very difficult; indeed, in most cases it determines itself. We start, in every case, to shadow the horizontal meridian; i. e., we rotate our mirror horizontally, from side to side. If there is no astigmatism, and the eye is spherical, the shadow (supposing there to be a shadow) has a crescentic edge which lies vertically on the pupil. If the eye is astigmatic, the edge of the shadow will usually (not invariably) be straight, and if the astigmatism is an oblique one, it will be tipped in the direction of one of the chief meridians.

Thus we are advised at the very outset of the existence of an oblique astigmatism, and of the axis of one of the two chief meridians. We immediately proceed to do our shadowing at right angles to this axis (as shown by the edge of the shadow) until we abolish the shadow in that meridian. The axis of the other chief meridian is, of course, at right angles to the first, and we therefore next proceed to do our shadowing across this opposite meridian until we abolish the shadow there also.

If, however, the eye has a right astigmatism, in which the two chief meridians lie vertically and horizontally respectively, as we start to shadow horizontally there will be nothing to tell us of the existence of astigmatism except perhaps the straight edge of the shadow. In this case we must simply proceed to abolish the shadow in this horizontal meridian. When we get this meridian almost neutralized, so that the light area begins to change to a yellow color, a series of lines of reddish-brown light will appear, lying horizontally across the pupil, seeming to shine through from behind. This appearance, known as the "astigmatic band," indicates astigmatism, and is due to the fact that while one meridian is now almost focussed, the other is yet unfocussed.

Whether we see any or all of these signs, or none of them, the presence of a right astigmatism can very easily be ascertained if, when we get the horizontal meridian neutralized,

we shadow the vertical meridian with the same neutralizing correction. If that also is neutralized, then there is no astigmatism; but if there is still a shadow moving in that meridian, there is an astigmatism, and we must proceed accordingly. This holds good, also, with regard to oblique astigmatism; and it is an excellent rule never to regard our skiascopic job as finished until we have shadowed the eye this way and that, to see if any meridian still remains uncorrected.

THE ASTIGMATIC BAND.

Many authors and practitioners greatly emphasize the importance of the astigmatic band, and rely upon it for determining the axis of one of the principal meridians. It has already been stated that its appearance is due to the fact that one meridian is corrected and the other is not. Jackson explains the phenomenon on the ground that "the retinal image will be more magnified in the direction of the principal meridian to which the nearer point of reversal belongs." Every point of light in that meridian then appears as a line of light running in the direction of the principal meridian whose point of reversal is at the operator's eye.

If this astigmatic band is to be made the chief factor in differentiating the axes of astigmatism, special care must be exercised in technique to bring it out as clearly as possible. Jackson has laid down the rule that "the band-like appearance is most perfectly developed when the observer's eye is at the point of reversal of one principal meridian and the immediate source of light is at the point of reversal of the other meridian."

Manifestly, this dual condition cannot be attained with the use of the self-illuminating retinoscope, since the source of light in that instrument is practically fixed at a point very near to the mirror, and even the slight up-and-down play that is allowed the lamp in some instruments is not sufficient to afford any appreciable adaptation to Jackson's rule. In order to make the most of the astigmatic band, therefore, the operator must make use of an independent source of light, which must be so arranged that he can move it toward and away from his mirror at will.

With this arrangement at hand, as soon as the principal meridian that he is shadowing becomes neutralized, he should push the lamp away from his mirror, or bring it nearer, as necessary, until it approximates the conjugate focus of the uncorrected meridian, when the astigmatic band will stand out clear and distinct, and the true axis of the astigmatism be revealed.

CALCULATING THE ERROR.

Having found, by skiascopy, the refraction of the two chief meridians in astigmatism, the error and correction are calculated exactly as in any other test for astigmatism, and according to the rules given in the section on Astigmatism. The astigmatic error is always the difference—the algebraical difference—between the two meridians. Theoretically, it matters not whether this difference be corrected by a plus or a minus cylinder. Having thus made the two meridians alike, the balance of the error, and of the correction, is spherical, to be treated accordingly.

IRREGULAR ASTIGMATISM.

The interpretation of this condition by retinoscopy is exceedingly puzzling. The shadow moves inconsistently; with in some meridians, against in others; and the appearance of the pupillary area is often a mixture of light and darkness. In order to refract such an eye with the retinoscope, the operator must find the best position of observation, and pick out the meridians which offer the clearest shadow phenomena.

SCISSORS MOVEMENT.

Occasionally, in carrying out a retinoscopic examination, the shadow, instead of moving regularly from one side of the eye or the other, seems to divide into two, and the two halves approach each other like the blades of a pair of scissors, hence the term, scissors movement. Sometimes this phenomenon signifies irregular astigmatism, but more often it is due to a tilting of the crystalline lens or a lack of alignment in the optical media. In such cases Sheard lays down two rules: (1) Be sure to refract the eye along the line of light; (2) If scissors movement occurs, watch carefully for the position of

the division line, and refract that portion of the eye in which the reflex contains within itself the visual line.

NEUTRALIZING WITH SPHERE AND CYLINDER.

Perhaps the simplest and most satisfactory method of all to apply skiascopy to the astigmatic eye is to employ a combination of spherical and cylindrical power for neutralizing purposes. The technique is as follows:

Having placed the objective working lens in position, and holding the retinoscope at the focal length of this lens, reduce the shadow with spherical neutralizing lenses (plus or minus, as may be indicated) until one meridian is neutralized, and the astigmatic band and other signs indicate the axis of the uncorrected meridian. Then apply cylinders (plus or minus as called for), axis to coincide with the band, until the other meridian is neutralized. The neutralizing lenses in the frame, aside from the working lens, will then represent the proper correction, without the need of any mathematical calculations.

DYNAMIC SKIASCOPY.

Dynamic skiascopy is a method of retinoscopy devised and demonstrated by A. Jay Cross, of New York City, some fifteen years ago, for measuring the refraction of the eye by means of the retinoscope with the ciliary muscle in contraction, i. e., with some of the accommodation in force. Cross based his working theory upon two physiologic principles: (1) That a muscle in action will accept assistance more readily than a muscle at rest, and (2) That convergence and accommodation are ineluctably bound together in the ratio of three to one (i. e., 3 prism dioptres of convergence to 1 dioptre of accommodation), which the patient will maintain at any fixed distance in spite of anything that is done to try to break it.

The technique generally employed is as follows: A row of letters is attached to the top of the mirror of the retinoscope, which the patient is required to read during the test; the point of fixation thus being the mirror itself, which is held at any convenient distance from the patient's eye. Cross avers that it is immaterial whether one eye be covered or both remain uncovered during the test, as convergence will be made for the point of fixation in either case.

Let us assume that the mirror is held at 50 cm. working distance from the patient's eye. As this demands 6 prism dioptres of convergence, the patient will immediately put in force 2 D. of accommodation and maintain that amount. If he is emmetropic, this 2 D. is all the accommodation he is using. The point of fixation is then conjugate with the retina, and no shadow is observable.

If the patient is hyperopic 2 D., but has no spasm of the ciliary muscle, he will, under the same conditions of test, put 2 D. of accommodation in force, but this will not make his retina conjugate with the mirror at 50 cm., being, in fact, just sufficient to make it conjugate with infinity. The emergent waves are now neutral, and the shadow moves with the mirror. We add plus 1 D. lens power, the patient still maintaining his 2 D. accommodation; we now have plus 3 D. in force—1 D. lens and 2 D. accommodation—still not sufficient to focus the emergent waves on the mirror. The shadow still moves with. The addition of another 1 D. will give us 4 D. plus power—2 D. lens and 2 D. accommodation. This will be sufficient to neutralize the 2 D. hyperopia and focus the emergent waves at the 50 cm. position of the mirror, abolishing the shadow.

If we place any additional plus power before the eye, the patient will still pertinaciously maintain his 2 D. accommodation, in ratio with his convergence, and we shall have an excess of plus power, focussing the emergent waves between the eye and the mirror, giving an "against" movement of the shadow. The highest plus lens power, then, with which the shadow can be neutralized, making no allowance for working distance, is, according to Cross, the measure of the hyperopia and its distance correction. And, if there is no ciliary spasm, this finding will coincide with that of the static retinoscopic test.

It must be borne in mind that in arriving at the finding of the static test, allowance has to be made for working distance, because the static test is really a test at infinity, which the working lense simply permits us to make at a nearer point for sake of convenience. In dynamic skiametry the accommodation of the patient's eye, fixed on the mirror, furnishes

working-distance power, and it does not, therefore, have to be allowed for in lens power.

Suppose, again, that the patient is 2 D. hyperopic, and has a ciliary spasm of 1 D. Upon fixing the mirror at 50 cm. this patient makes 2 D. active accommodation, in accordance with his convergence-accommodation relation. He now has in force 3 D. plus power—1 D. spasm and 2 D. active accommodation. As it takes 4 D. to make the mirror conjugate with his retina (2 D. to neutralize the hyperopia and 2 D. to equalize the 50 cm. distance), he is still short 1 D. We place 1 D. plus lens before the eye. We now have the total 4 D. necessary to make retina and mirror conjugate, and the shadow is abolished.

We now go on and add another 1 D. plus lens. Here we come to the very crux of Cross' theory. According to his doctrine, the patient, rather than break the relation between his convergence and his accommodation, will surrender his 1 D. ciliary spasm, and the conjugate relation of mirror and retina will remain unchanged—there is still no shadow. The addition of another .50 D. plus lens, however, will give us an excess of plus power, and cause the shadow to move "against."

In this case the highest plus power with which we are able to find a point of reversal is 2 D., as in the former example, but in this instance it will not coincide with the finding of the static retinoscopic test, which would show but 1 D. of error, the other 1 D. being locked in a spasm at infinity. According to Cross, therefore, if there be more plus lens in the dynamic finding than in the static, the difference represents ciliary spasm.

There are two objections to Cross' theory, one a hypothetical objection, the other a clinical one. First: According full recognition to the soundness of the physiological principle that a muscle in action accepts aid more readily than a muscle at rest, yet, in view of the pertinacity of most of these ciliary spasms, it would seem doubtful, to say the least, whether the accommodation-convergence imperative is sufficiently strong to force a surrender of the spasm in preference to breaking the three-to-one ratio. (We say nothing about permanent ciliary contractures, because no theory, of course, could contemplate the surrender of them under test.) This

doubt becomes still more insistent in view of what we know as relative accommodation.

Second: Clinical experience has demonstrated, over and over again, that, where dynamic skiametry has given a larger plus finding than static retinoscopy, and correction accordingly given with a view to developing the latent error thus alleged to be indicated, no latent error has ever developed. In the early days of dynamic skiametry, when Cross' theory was accepted at its face value, practitioners were in the habit of giving full distance correction in accordance with the dynamic finding, although it fogged the patient badly, believing that in a little while the uncovering of the spasm would adjust the correction to their vision. In the vast majority of cases, however, this happy outcome did not eventualize; patients came back to have their glasses changed, or they went somewhere else and were lost to the dynamic practitioner; and so the practice was at length abandoned.

The probabilities, therefore, are strongly against the soundness of Cross' working theory; and we understand that even Mr. Cross himself no longer holds to his original interpretation of his test, which, nevertheless, remains a most valuable procedure. The truth is, there is considerable difference of opinion as to the proper interpretation to be placed on the findings of dynamic skiametry, even among those who are most expert in its employment. Sifting this varied opinion out, we may, perhaps, classify it into three principal groups.

1. The followers of Cross still continue to hold the general view that the dynamic finding indicates the full distance correction, but not necessarily the correction that can or should be given the patient. It represents, in fact, the limit of ciliary relaxation in the individual case, in much the same way as the finding under atropine does. The objection to this view is that it has but little clinical value. All that it affords the practitioner is a hint of the probable (or possible) extent to which the patient may be expected to accept plus correction in the course of time—all of which, however, has still to be worked out from time to time if so be that the patient does develop the need for additional plus correction.

2. A more modern group of refractionists regard dynamic skiametry as valuable method of demonstrating and working out conditions of accommodative inefficiency. They make a distinction between insufficiency of accommodation and accommodative inefficiency. The former is, of course, presbyopia, whether normal or premature; the latter means that the ciliary muscle is not properly innervated. The condition in question will be found discussed in the chapter on Accommodation. According to this view, the excess plus finding of the dynamic over the static test represents the ciliary deficiency in that particular case for the point at which the dynamic test is made. Under this interpretation the dynamic test is essentially a near-point test, and would not be used as the basis of a distance correction. It would be a question for the practitioner's judgment whether he would prescribe reading correction to help the inefficiency disclosed by the test—the answer depending chiefly on the degree of eyestrain that was present.

3. A third group, instigated and headed by Sheard, is probably nearest the truth in believing that the excess difference between the static and the dynamic finding represents the negative relative accommodation of the eye, i. e., the amount that it can be forced to surrender without changing the convergence. Not only is such a view of the matter the most rational, but from such a standpoint dynamic skiametry assumes the highest practical value. It becomes an excellent method of determining the reserve accommodation power and the flexibility of the accommodation-convergence function; and affords a means of finding the point at which accommodation and convergence coincide.

Under this view, however, the technique of the test is somewhat different from the original Cross technique. To begin with, the full distance correction should first be ascertained, and put on. We will first consider the application of the test to the determining of the amount of reserve accommodation. With the patient's accommodation fixed on the retinoscope at a given near point—say 33 cm., we note the movement of the shadow. If neutral, we come closer to the eye until the motion is "with," then drawing back until it is neutral again.

The closest point at which we can still get a neutrality of shadow is the comfortable near point. Converting this into dioptres by dividing it into unity gives us the maximum amount of accommodation that the patient can use without eye-strain, and deducting this from his total amplitude of accommodation, gives the exact reserve accommodation required in this particular case.

The ratio between the total amplitude and the required reserve will determine the necessity, or otherwise, of affording the patient aid by means of reading glasses. If, for example, his total amplitude is 5 D., his comfortable near point at 25 cm., which is equivalent to 4 D. of accommodation, showing a required reserve of 1 D., near glasses are evidently not called for. If, on the other hand, his total amplitude is 5 D., his comfortable near point the equivalent of 1 D., showing a required reserve of 4 D., near glasses are called for in spite of the 25 cm. near point.

When, as sometimes happens, in making this test, the shadow movement continues "with" at all convenient distances, extra plus lens power may be placed before the eye, the test proceeded with, and the extra plus lens allowed for in making the final calculation.

For the purpose of determining the coincidence of accommodation and convergence, Sheard's modification of the above test is applicable. Full distance correction should be worn during the procedure. The patient is allowed to select the distance at which he ordinarily reads, or does the near work for which he desires comfortable vision, and the test is made at this distance. With the accommodation fixed on the retinoscope at this distance, the maximum plus or minimum minus lens is found which just suffices to give a neutral shadow, not carrying the correction to a point where it reverses the shadow. This lens power represents the coincidence of accommodation and convergence.

Sheard carries this test a step further for the purpose of ascertaining the flexibility of the dual function, by trying out both the positive and negative accommodation at the point in question. According to Donders' rule, "The accommodation can be maintained only for a distance at which, in reference

to the negative part, the positive part of relative accommodation is tolerably large. If, therefore, the relative test does not fulfill this condition—i. e., if the positive relative accommodation is not considerably larger than the negative—then that furnishes still further ground for supplying the patient with reading assistance, as indicated by the dynamic test.

Sheard, therefore, believes that dynamic skiametry, when properly practiced, affords a quick and accurate method of finding the lens assistance needed at reading distance to re-establish the normal relations between the positive and negative ranges of accommodation and the convergence.

THE NEAR POINT BY SHEARD'S METHOD.

Sheard further holds that the near point cannot be accurately found by dynamic skiametry as it is usually practiced. For this purpose he uses the following technique:

The fixation chart is pushed in advance of the retinoscope. With full distance correction on, the patient's attention is directed to the chart held two or three inches in front of the mirror, and the operator notes the movement of the shadow. If it is "with" he pushes the chart forward until it becomes "against." He then comes forward with the mirror until it is "with" again; and so on, until, with the chart some distance in front of the mirror, he locates the nearest point of neutrality, which denotes the true near point of the patient.

The working principle of this procedure is that the patient must fix a point well within his near point, the observer coming up from behind to locate the neutral shadow, which must be the true punctum proximum.

Retractor. An instrument for holding back, or open, parts of the body during operation, as lid retractors.

Retrobulbar Neuritis. See **Neuritis, Optic.**

Reversal. In optics this term is specifically applied to the changing of a light-wave from one of positive curvature to one of negative curvature, or the opposite.

Point of Reversal. In the changing of a negative, or minus wave into a positive, or plus one, it is necessary that the minus wave be brought to a focus, from which it starts to expand into a positive wave. This focal point where the change oc-

curs is technically known as the point of reversal. The term is specifically applied to the reversal of the emergent waves from the eye in retinoscopy.

Rhytidosis. Wrinkling.

Right-Eyed. Having the right eye the dominant eye.

Robertson, Argyll, Pupil. See **Argyll Robertson Pupil.**

Rods and Cones. See **Retina.**

Rotation. A method of determining the the polarization of light (See **Polarization**).

Rotation of the mirror is the technical term describing the tilting of the mirror on its stem axis which is used in the technique of retinoscopy. (See **Retinoscopy.**)

Sarcoma. A form of malignant tumor characterized by large-cell elaboration of embryonic tissue. It sometimes attacks the orbit of the eye.

Schematic Eye. A model eye, built on the same plan as the human, for purposes of study and experiment.

Schematic Eye.

Schlemm's Canal. See **Canal.**

Scissors Movement. A movement of the shadow in retinoscopy resembling the movement of a pair of scissors, i. e., instead of the two sides of the shadow moving laterally and conjugately, they move toward and away from each other. It indicates irregular astigmatism. (See **Retinoscopy.**)

Sclera. Sclerotic. The outer coat of the eyeball, extending from the optic nerve forward to the insertion of the cornea. It is firm and white, and relatively thick, especially at the back, where it has a thickness of about 1 mm. It gives shape and support to the globe, and serves as the dark box of the camera of the eye. It is composed of connective tissue, and to it are attached the extrinsic muscles.

Scleractasis. Bulging of the sclera.

Scleriritomy. Incision of the sclera and iris for the relief of anterior staphyloma.

Sclerochoroiditis. Joint inflammation of the sclera and the choroid.

Sclero-Conjunctival. Pertaining to the line of junction between the sclera and conjunctiva.

Sclero-Corneal. Relating to the margin of junction between the sclera and the cornea.

Sclero-corneal Sulcus. The depression formed in the sclero-corneal margin by the difference of curvature of the sclera and cornea, respectively.

Sclero-Iritis. Inflammation of the sclera and iris.

Sclero-Kerato-Iritis. Inflammation of the sclera, cornea and iris simultaneously.

Scleronyxis. Perforation of the sclera.

Sclerophthalmia. A condition in which the sclera encroaches on the cornea, so that only the central portion of the latter is transparent.

Sclerosed. Hardened.

Sclerotic. See **Sclera.**

Scleroticectomy. Cutting of the sclera.

Scopolamine. An alkaloid, identical with hyoscine, which, when instilled in the eye, produces midriasis. It is sometimes employed in preference to homatropine. Its action is transitory.

Scotodinia. Dizziness and dimness of vision.

Scotoma. A dark spot in the visual field, due to a corresponding blind spot on the retina. When the retinal area is totally blind the scotoma is called absolute. See **Perimetry.**

Scotometer. An instrument for determining the position and extent in the visual field of scotomata, from which data one is able to locate the retinal lesion which is responsible for them.

Sebaceous Cyst. Infection and swelling of one of the sebaceous glands of the eye.

Second Sight. In the early stages of certain cataracts, the crystalline lens swells without undergoing, as yet, much opacity. This swelling of the lens increases its curvature, thus offsetting a good deal of the patient's presbyopia, and as a consequence these patients are often able to read, for a period, without their glasses. This is known as second sight. The patient, ignorant of the cause, is usually very proud of the feat; but to the ophthalmologist, of course, it is a serious indication of approaching trouble.

Segment. A piece cut out of a circle or sphere. All lenses are segments of a sphere or of a cylinder.

Senopia. Second sight, q. v.

Serpiginous. A term applied to a certain type of corneal ulcer which creeps rapidly over the surface in serpentine form. It is a very grave condition.

Shadow Test. Same as retinoscopy.

Sheath. A tubular case or covering. All large nerves are furnished with sheaths, for insulation purposes. The sheath of the optic nerve is an extension of the dura mater of the brain.

Short-sightedness. A colloquial term for myopia.

Sideroscope. A magnetic instrument for determining the presence of a piece of metal in the eye.

Siderosis. A characteristic condition, including a rusty-brown discoloration, which is seen in the eye as the result of the long-continued presence of a piece of metal in it.

Sine. A term in trigonometry, to express curve measurement in linear fashion. The sine of an arc is a line drawn from one end of the arc perpendicularly upon the diameter drawn through the other end of the arc. The sine of the arc is also the sine of the angle subtending the arc.

The relative values of the sines of the angles of incidence and refraction constitute the index of refraction.

Skiascope. Same as **Retinoscope,** q. v.

Skiascopy. Same as **Retinoscopy,** q. v.

Snow-Blindness. Exhaustion of the rods and cones of the retina, due to long exposure to the white light reflected from snow.

Socket. The cone-like hollow formed by the bones of the orbit into which the eyeball is set.

Spectacles. Strictly speaking, the word spectacles refers to the lenses which are adjusted to the human eye to correct defects of vision, the containing parts being known, in the case of bow-spectacles, as the frame, and in the case of eye-glasses as mountings. Recent usage, however, has tended to apply the term to the mechanical parts, rather than to the lenses; and it will be so considered and defined here.

Spectacles and eye-glasses are made either with or without rims, or, as the opticians call them, eye-wires. In the rimmed variety a pair of spectacle frames consists of the eye-wires, end-pieces, temples and bridge. The end-pieces, four in num-

ber, are attached in pairs to the outer sides of the eye-wires; one end-piece is furnished with a projecting pin, or dowel, which fits into the receiving hole on the opposite piece. Both pieces are pierced with a threaded hole for the screw. The temple is flattened at its near end and pierced with a hole corresponding to the pin on the end-piece. The temple is placed between the two end-pieces, the pin passing through the hole in the temple into the receiving hole in the opposite end-piece. A screw is then driven through the threaded hole in the end-pieces, so as to hold the lens in place in the tautened eye-wire and the temple between the end-pieces. The temples revolve on the pin inward, but are prevented from revolving outward by a small flange on the temple. The bridge is soldered to the inner sides of the eye-wires.

In rimless spectacles the general arrangement is the same, but the end-pieces, and the bridge, are attached to the lenses themselves by means of small clutches which are screwed onto the lenses through holes drilled in the glass.

Of late years the metal eye-wires of rimmed glasses have been replaced by rims made of various kinds of shell. These rims are shrunk onto the edge of the lens by first heating them and then allowing them to cool in place, just as metal tires are shrunk onto a wheel. The bridge is attached to the shell rim in various ways.

TEMPLES.

Fundamentally, the only two varieties of temple are those which curl around the back of the ear and those which do not, the only practical difference being one of comfort and stability. The former "hook" or "riding bows" are better for constant wear, the latter, or "straight," for patients who have to be continually taking them off and putting them on. Some of the riding bows are made of flexible material and are known as "cable riding bows," in distinction from the firm variety, which are called "curls." Temples are also made, nowadays, of shell.

BRIDGES.

As the bridge is the part whose shape and position regulates the lateral and vertical relation of the lenses to the eyes,

its adjustment is a matter of great importance. There are innumerable varieties of bridges, which it would be folly to attempt to enumerate, far less describe, here. They may be found in the catalogs of various optical houses. They fall, however, like temples, into two fundamental classes, namely, the wire and the saddle bridge. The former are intended to be shaped to the nose and are adaptable to persons having well-shaped noses; but for the average nose a saddle bridge, made in the shape of a letter K, which may be as flat or as deep as desired, serves the purpose best.

EYE-GLASSES.

In eye-glasses, of course, there are no temples. On the right outer side of the eye-wire in rimmed eye-glasses, of the lens itself in rimless ones, the end-piece is enlarged into a post and handle with which to manipulate the glasses. To the inner sides of the rims or of the glasses are attached the nose-piece, which is usually furnished with a guard of some resilient material to keep it from abrading the nose.

SPRING AND NOSE PIECE.

In eye-glasses the bridge of the spectacle is replaced by the spring and the nose-piece. Like the bridges of spectacles, their variety is legion, and they obey the same principles as the bridge, namely, in determining the position, plane, and distance from the eyes, of the lenses, according to the different angle at which the guards are attached to the lenses or rims and the distance above or below center at which the studs are attached to the lenses.

STUDS.

In eye-glasses, as in spectacles, it is often necessary to set the lenses forward or backward, according to the prominence or shallowness of the nose and eyes. This is done by means of special studs, known as inset and outset studs.

Spectrum. The differentiation of the white pencil of light into its constitutent color waves. See **Color.**

Sphenoid. One of the bones of the orbit. It is a peculiarly-shaped bone, somewhat like a bat with extended wings, and articulates with every other bone in the orbit.

Sphere. This word is used to designate, shortly, a lens whose surface is a segment of a sphere. See **Lens.**

Spherometer. An instrument for measuring the curvature of a sphere.

Sphincter. A ring-shaped muscle which contracts concentrically. The eye has two such muscles, the sphincter iridis and the ciliary.

Spintherism. A condition in which the patient sees stellar flashes of light.

Squint. See **Strabismus.**

Staphyloma. A cone-like bulging of one of the tissues of the eye. An anterior staphyloma is a bulging forward of the cornea; a posterior staphyloma is a bulging backward of the sclera and choroid. In either case, of course, it lengthens the eyeball, and tends to create a condition of myopia. It is therefore associated with myopia, especially high myopia. It also renders thin the tissue that is bulged, by stretching it.

Static. In a state of rest. Static refraction is measurement of the dioptrism of the eye while the accommodation is not in force.

Stenopaic Slit. An opaque disc with a linear slit in it, which, when placed before the eye, permits light to enter it along one meridian only. It is used for detecting and measuring astigmatism. (See **Astigmatism.**)

Stereoscope. Under this name are included two types of optical instruments, (1) those which are designed to assist and enlarge, and in some instances even to replace, the stereoscopic faculties of the eye, and (2) those which present plane pictures to the eyes in such a way as to create the semblance of depth and solidity. All binocular optical instruments, including spectacles, and certain specially constructed apparatuses, come within the first class. It is the second class, however, that we usually understand by the term stereoscope.

The prime element in stereoptic vision is the parallax, i. e., the different view of the object experienced by the two retinae by reason of viewing it from different angles. This is the principle of the stereoscope. It enables us to look simultaneously at two photographic pictures, taken under a difference of angular view, corresponding to, or even greater than, the separation of the two eyes, and thus, as in ordinary vision, the two images are fused by the brain, and the objects thus viewed are made to stand out in relief.

Wheatstone invented a reflecting stereoscope, compounded of mirrors, in 1839, which never attained any worthwhile results, partly because of its unwieldy shape, and partly because of the impossibility of obtaining equal illumination on the two pictures. Later, Sir David Brewster invented a refracting stereoscope, made with prisms, upon which all the modern stereoscope now in use are modeled.

Stereoscopic Vision. Binocular vision in which solid objects stand out in solid form, or, to use the technical expression, in relief, and not as flat pictures. For a detailed description of this faculty see **Binocular Vision.**

Stillicidium. Overflow of tears due to stricture of the ducts.

Stilling's Canal. See **Canal.**

Stilus. An instrument used for dilating the tear ducts.

Stop-Needle. A needle used for piercing the cornea, with a shoulder to limit the depth of penetration. The most commonly used is the Bowman stop-needle.

Strabismus. A state of permanent deviation of one or both visual axes from parallelism. It may occur as the result of paralysis of one of the ocular muscles (paralytic strabismus), or as the result of muscular imbalance due to error or refraction (concomitant strabismus). In addition, there must be mentioned a condition known as apparent strabismus, due to an exceedingly wide angle alpha in hyperopia or an exceedingly narrow one in myopia, which gives the eyes the appearance of turning outward and inward, respectively. This condition is

easily distinguished from real strabismus by demonstrating the absence of diplopia under proper tests.

DIFFERENTIATING REAL STRABISMUS.

Since strabismus is in reality a permanently manifested imbalance, it is subject to the same principles and methods of test as heterophoria. Thus, the distinction between paralytic and concomitant strabismus rests upon the same principle, and is made in the same way, as that between anatomic and functional imbalance.

(a) If the deviating eye be made to follow a small object moved laterally before the eye, it will be seen to lag, or to stop entirely, in the field of movement of the affected muscle, wheras in concomitant squint there will be little or no limitation of these conjugate movements.

(b) The patient is made to fix a point at infinity, first with the sound eye, the affected eye being covered, but so that the operator can observe it, then with the bad eye, the sound eye being covered in like manner. The amount of deviation made by the covered eye from the median in each case is measured by means of a pair of calipers; that which is made when the sound eye fixes being known as primary deviation, and when the bad eye fixes as secondary deviation. In paralytic strabismus secondary deviation is greater than primary, because of the exaggerated innervation required to fix with the paralytic eye. In concomitant squint primary and secondary deviation are equal.

Paralytic squint is usually the result of an infectious disease, such as diphtheria, scarlatina, etc., which poisons the peripheral nerve supplying the ocular muscle, or else of a central nerve lesion in the brain, due to syphilis, tuberculosis, meningitis, brain tumor, etc.

CONCOMITANT STRABISMUS.

This name is given to functional, refractive strabismus because, as stated, in conjugate excursions the two eyes keep pace with each other. Only in the performance of convergence, positive or negative, are the excursions of the two eyes unequal. This type of strabismus is the result of refractive error.

Internal concomitant strabismus, where the deviating eye or eyes turn inward, is usually the outcome of hyperopia, where the patient has given up trying to maintain fusion under the strain of esophoria, and one or both eyes are permitted to take up a permanent position of stable equilibrium, with the visual axes converging. There is diplopia, of course, but the patient —especially if it be a child—finds it easier to disregard the false image in the deviating eye than to endure the annoyance of maintaining unstable equilibrium in the muscles. In some cases the patient uses one eye exclusively, all the time, allowing the other to deviate continuously, and disregarding its image; in which event the attentive visual faculty of the unused eye is gradually lost, and it becomes amblyopic (amblyopia ex anopsia). In other cases, the patient uses first one eye and then the other, allowing the other to deviate alternately (alternating strabismus); and in this form of squint the visual acuity of both eyes is retained entire.

In the rather rare cases where both eyes are permitted to deviate, it is extremely difficult for the patient to fix at infinity except when one eye is covered.

External concomitant strabismus, where the deviating eye turns outward, cannot so uniformly or definitely be ascribed to myopia, although it usually occurs in myopic people. Such a variety of squint is, in fact, extremely rare, as explained under heterophoria. Most cases of external strabismus are paralytic, or, at least, anatomic, in their origin.

There is no paralysis of the muscle in concomitant squint, at least at first, although long continuation may develop in the deviating eye a partial paralysis from disuse. In alternating squint, of course, this does not occur.

DEGREES OF STRABISMUS.

Strabismus is measured in the same way as imbalance, namely, by the amount of prism power required to fuse the images. No dissociation is needed, of course, the purpose of dissociation being to turn an imbalance into a squint, and here the transformation has already been done by the patient.

The base of the measuring prism is always to be placed over the "weak" muscle, i. e., base out when measuring internal strabismus and base in when measuring external squint.

There are various mechanical methods and devices for measuring the amount of deviation in a squinting eye. A rather crude method is by means of the strabismometer, consisting of a handle supporting a small ivory plate shaped to the lower eyelid, and having on it a millimeter scale by which the amount of deviation can be read off while the sound eye is fixing at infinity.

A better method is to measure the angle of deviation by means of a perimeter, consisting of a central rest for the patient's face and a hemispherical quadrant on a level with the patient's eyes. With the patient seated at the center, with his eyes fixing infinity, the operator moves a lighted candle, or tiny electric bulb, slowly along the inside of the quadrant, following it with his own head, until it reaches the place where the reflected image of the light is exactly in the center of the patient's deviating pupil. A scale on the quadrant shows the angular deviation.

TREATMENT OF STRABISMUS.

The treatment of paralytic strabismus really belongs in the province of the medical man, and consists principally in treating the constitutional condition underlying the paralysis. However, proper correction of refractive errors, if any exist, and intelligently directed muscle exercises are of considerable aid. (See **Muscle Exercises.**) Where these measures fail, tenotomy or advancement may be performed for esthetic effects.

The treatment of functional strabismus, like that of heterophoria, is a matter on which no dogmatizing is possible. In each individual case the refractionist must use his best judgment.

In arriving at a decision, we usually recognize three degrees of severity: (1) Where the reflected image of a candle-flame, held about a meter from the deviating eye, in the median line, falls within the pupillary area, (2) Where this image falls outside the pupil but within the cornea, and (3) Where it falls outside the cornea, i. e., there is no corneal reflection. In squint of the first degree, it is almost certain that proper glasses and muscle exercises will correct it, provided there is good vision in the squinting eye. In squints of the second de-

gree, there is a balance of possibility of success and failure, only to be decided by trying. In third degree squints it is almost certain that an operation will have to precede other means of cure.

Needless to say that accurate refraction is the first sine qua non of treatment. In many cases of esotropia, due to hyperopia, especially in young children, this is sufficient; under the correction, the eyes gradually resume their normal state. In others the correction has to be supplemented by properly arranged muscle and prism exercises designed to re-educate the patient in the faculty of fusion. For a full discussion of this procedure see **Muscle Exercises.**

The most difficult problem is presented in cases where the deviating eye has become amblyopic. Here, both correction of refraction (so far as the amblyopic eye is concerned) and education in fusion are impossible. Attention must first be directed toward restoring visual function to the bad eye until it reaches a point where it can be induced to do team work with the good one. A simple method of doing this is to instruct the patient to cover the good eye with a bandage or patch for several hours a day, and force the use of the amblyopic eye. A more scientific and rapid method is by the use of the amblyscope, which educates the visual acuity of the eye and the muscle sense at the same time. For technique of its use the reader is referred to the section on **Amblyscope.**

Strabotomy. The same as tenotomy.

Stye. See **Hordeolum.**

Subconjunctival. Underneath the conjunctiva, between it and the sclera.

Subjective. In physiology this term denotes phenomena which occur as sensations and experiences within the individual's own consciousness.

In optometry, subjective tests are those which depend for their findings upon what the patient tells us of his own feelings and perceptions. The principal subjective test is that of read-

ing the letters on the chart, and discerning the spokes of the astigmatic wheel.

Sublatio Retinae. Detachment of the retina.

Subluxation. A partial displacement of the lens, by which it is slightly tilted. It manifests itself by an inequality in the depth of the anterior chamber of the eye. Its diagnosis and treatment belong to medicine.

Suborbital. Beneath the orbit.

Subretinal. Underneath the retina, between it and the choroid.

Subvolution. An operation for pterygium, in which the growth, after being split and cut, is buried beneath the conjunctiva.

Superciliary. Pertaining to the eyebrows.

Supraorbital. Above the orbit.

Sursumduction. The turning of one of the eyes upward by the superior rectus muscle—which also implies the turning of the other eye downward by the inferior rectus.

Sursumduction is tested by the amount of prism, base up or base down, as the case may be, which the eyes are able to overcome and still maintain single vision.

Suspensory Ligament. A circle of delicate, homogeneous fibres, taking their rise from the inner surface of the ciliary body, close to the ora serrata, which surround the crystalline lens and hold it it place. It is also called the zonula ciliaris.

Symblepharon. Sticking, or growing together of the eyelids.

Sympathetic Ophthalmitis. An inflammation of one of the eyeballs due to injury or disease of the other eye. The communication takes place through the consensual fibres of the optic nerve and the sympathetic ganglia of the fifth nerve.

Synchysis. Liqueification of the vitreous. It is made manifest by the floating about of opacities in the humor. It may occur as one of the ordinary events of old age; but in younger life is a sign of disease of one of the adjacent tissues.

Synechia. Adhesion of the iris to the lens (posterior synechia) or to the cornea (anterior synechia), due to exudative inflammation of the iris, in which sticky exudates are poured out which glue the iris to one of these bodies. It is to prevent synechiae that the oculist uses atropin in diseases of the iris and cornea, in order to draw the iris up out of reach of the lens and cornea.

Synizesis. Contraction of the pupil.

Synophthalmus. A one-eyed monster.

Syntropic. A condition in which the eyes are both turned in one direction. Conjugate deviation of the eyes.

System. In optics the word denotes a combination of lenses or mirrors, in series, whose joint action produces the optical effect desired.

T. An abbreviation for the intra-ocular tension.

Tabes Dorsalis. Another name for locomotor ataxia. One of its earliest symptoms is the Argyll Robertson pupil, i. e. a pupil which does not contract in response to light stimulus, but contracts during accommodation. It is also frequently accompanied by optic atrophy.

Talbot's Law. A law of illumination. If a represents the duration of the flash, b the duration of the eclipse, then a/a — b = the intensity of the illumination given by the flash.

Tangent. A line which touches the circumference of a circle or sphere, but, being produced, does not cut it. The normal of a circle or sphere is perpendicular also to the tangent at the point where the latter touches the circumference.

Tapetum. The pupillary reflex of lower animals, which, on account of the difference between their refraction and that of the human eye, is often visible to the human naked eye. In cats, it is seen as a green luminosity.

Tarsitis. Inflammation of the tarsus of the lid.

Tarsoplasty. Plastic surgery of the eyelid.

Tarsorrhaphy. Sewing of the eyelid.

Tarsotomy. Cutting of the tarsal cartilages.

Tarsus. The cartilaginous framework which gives shape and support to the eyelids.

Tears. The secretion of the lachrymal glands which continually pour into the eyes through the lachrymal ducts, keeping the membranes moist and clean, and are drained into the nose through the lacrymal sac and nasal ducts.

Substantially the tears consist of slightly salty water.

Teichopsia. A scintillation with a jagged outline.

Telescope. An optical instrument by which distant objects are brought within the range of distinct, or more distinct, vision. This it does in two ways: (1) It enlarges the entrance aperture of the rays by substituting its own objective lens or reflector for the human eye, thus gathering additional light from the object-space, and (2) It magnifies the image thus produced.

In its simplest form, the telescope consists of a tube, or set of sliding tubes, in which are an objective lens and an eye-lens, both convex. If the axes of the two lenses and their principal focal points (posterior and anterior, respectively) coincide, rays which are focussed into an image by the objective lens will emerge from the eye-lens as parallel rays, and are then focussed by the eye to form a magnified image on the retina.

There are two principal types of telescope, the refracting and the reflecting telescope. The former is constructed of lenses only, which, by successive refractions, produce the desired result. It is very essential that the objective lens, or series of lenses, be as free as possible from aberration, and for this purpose they are usually made of triplex glass, to correct this error. The aberration of the eye-lens is not of such moment.

The reflecting telescope is composed of specula, or concave mirrors, together with lenses, and is capable of much greater

range of action than the refracting type, besides avoiding much of the aberration that pertains to the latter. Newton, Gregory, Herschell and Lord Rosse all took a part in its development, and it is the type generally used in astronomical observations.

Telescopic Vision. Narrowing down of the visual field so that the patient sees as through a tube. It occurs in certain forms of concentric optic atrophy.

Tendon Recession. Moving a tendon of the eyeball further back to remedy strabismus. The opposite of advancement.

Tendons. The fibrous cords by which the extrinsic muscles of the eyeball are attached to the sclera. They have no power of contraction, but merely serve to transmit the pull of the muscle to the eyeball.

Tenonitis. Inflammation of Tenon's capsule.

Tenon's Capsule. See **Capsule.**

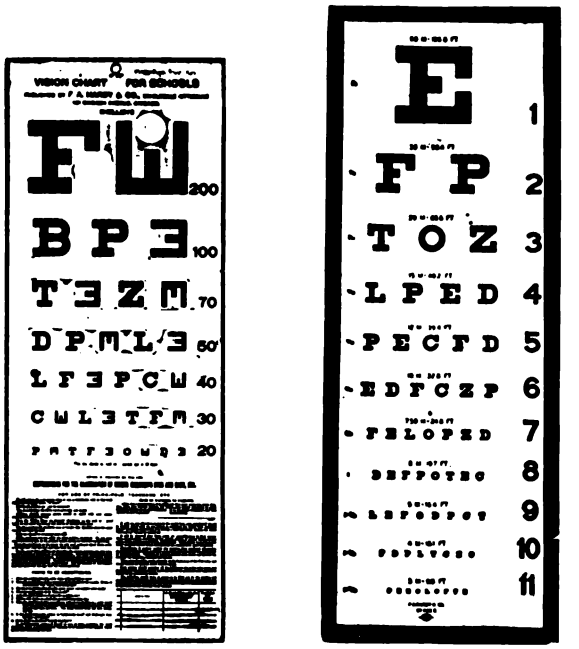
Tenotomy. Complete or partial dividing of the fibres of the tendons (see above) for the correction of strabismus. It belongs to the province of the eye surgeon.

Tensor Tarsi. A small muscle having its origin at the crest of the lacrimal bone and inserted into the tarsus at the inner canthus. It is supplied by the seventh nerve. By stretching the tarsus it compresses the lacrimal puncta and sac.

Test Chart. A chart with letters or geometrical figures on it for subjectively testing the visual acuity or the refraction of the eye. There are several varieties of test chart in use, of which the following are the commonest:

Snellen's Test Types. These consist of letters of varying size arranged in rows. Over each row is a number indicating the distance at which each letter in the row appears to a normal eye under a visual angle of 5 min. Each letter is inscribed in a square whose sides are divided by partition lines into five equal parts, so that each partial square (representing the detail of the letter) subtends a visual angle of 1 deg. in the

normal eye at the proper distance,—i. e. the minimum visual angle.



Test Charts.

The chart is used at a distance of 6 meters, or 20 feet, at which distance the patient should be able to read the letters marked for that distance, in which case we record his visual acuity as being 6/6, or 20/20. If unable to read this type, we record his acuity as being the distance-number of the type he ought to read divided by that which he is able to read. Thus, if at 6 meters he reads only the 8 meter type, we say his acuity is 6/8. Or, in feet, if at 20 feet he reads only the 40 feet type, his acuity is 20/40.

Snellen's types are the most commonly standard of all forms for distance vision.

Jaeger's Test Types. These are similar in scientific principle and construction to Snellen's, but are used chiefly in the smaller letters, for testing near vision.

Clock Dial Chart. For testing for astigmatism. It consists of a series of black lines radiating from a common centre at

the various angles of the circle. The test depends upon the fact that the lines on the chart corresponding to the patient's two chief meridians will be seen, respectively, clearest and faintest; and the cylinder which makes all the lines in the chart appear equally black will correct the astigmatism.

Pray's Test Types. These are modifications of the clock dial lines into the form of letters. They consist of a series of rather large letters, each being made up of black strokes, the strokes being made at a different angle for each letter. The two letters whose angular strokes correspond with the patient's chief meridians are seen blackest and faintest, respectively.

Practically all astigmatic charts are variations of the clock dial chart.

Test charts are used either with reflected light or with transmitted light—being, in the second case, made of some translucent material. They are also made in what is known as "reversed" form, i. e. with the letters or figures printed backward, so that they can be viewed in a mirror where the operator's space does not permit of his having an uninterrupted 6 meters or 20 feet range. For children and illiterate persons picture charts are substituted for letter charts.

Voerhoeff's Astigmatic Chart consists of two circular disks pivoted through their centre to a flat board, upon which degrees are marked off, so that the disks can be rotated to any desired angle. In one disk are drawn rectangular lines, through which run two dark lines at right angles to each other (principal meridians). In the dark disk are drawn concentric circles, through which run dark meridianal lines, similar to the wheel chart.

By the second disk the axis of the astigmatism is determined, by ascertaining the two chief meridianal lines. The first chart is then set with the two cross lines at the angles corresponding with the chief meridians of astigmatism, and the degree of astigmatism determined by comparing these two cross lines.

Parker has modified Voerhoeff's chart by omitting the two cross lines in the first section, and the concentric lines in the second.

Thomas' Astigmatic Chart consists of two cross-lines, each consisting of three detail lines separated by the proper visual

angle distance, which are made to revolve inside a graduated circle. The chief meridians are established by revolving the cross, and the astigmatism corrected by making the two sets of detail lines equally discrete and distinct.

Tests. It would be impossible to enumerate, far less to describe, in a work of this nature, all the tests employed by ophthalmologists and recorded in the literature of the subject for functional errors of the eye. We must be content to limit ourselves to the relatively few that have, by common consent, become standard. The details of these tests, and the principles upon which they are based, will be found in various parts of this book, under the headings to which they respectively belong. In this place all that will be given is a brief technical formulary for each of them.

SUBJECTIVE TESTS.

Visual Acuity. To be taken as a preliminary to every examination. First with both eyes in vision, and then with each eye separately, have the patient, seated six meters (20 feet) from the distance chart, with the chart under good illumination, read the lowest line he is able to read. With the number of this line as a denominator, and that of the normal as a numerator, we express the visual acuity in a refraction. Thus, if the patient is seated at a distance of 20 feet, the normal number is 20; if he reads only as far as line 40, his visual acuity is recorded as 20/40. See **Acuity, Visual.**

Pin Hole. To determine whether a lens can improve vision. Under the same conditions as stipulated above, place before each eye separately, (the other eye being meanwhile excluded), the pin hole disc, and ascertain if the patient can read any further down the chart, or any clearer, than without it. If so, the vision can be improved by a lens; if not, the eye is probably pathologic.

Fogging. An excellent subjective method for working out, at one and the same time, astigmatism and spherical error.

1. With the chart at 20 feet, place before the eye a plus lens strong enough to blot out both letters and wheel-lines.

2. Gradually reduce the plus power with minus lenses until the lines of the astigmatic wheel just become visible.

3. If one of these lines is decidedly blacker than the others, find a minus cylinder which, with its axis across the blackest line, makes them all equally clear.

4. Leaving the cylinder (if any) in place, continue to reduce the plus spherical power with minus spheres until patient can read 20/20 type.

5. The net amount of lens power represented by the lenses before the eye when this point is reached, (including the cylinder, if any, is the patient's distance correction.

If the patient has no astigmatism, then of course item 3 will be omitted, as there will be no apparent difference in the lines of the astigmatic chart.

Thus, assume that we fog with a plus 5 D. Reducing to 4 D. the wheel-lines become faintly visible, with the vertical line standing out clearest. A minus .75 D. cylinder, axis 180, makes them all equally clear. Leaving the minus, .75 D. cylinder in place, we go on reducing the spherical power until at plus 2 D. patient reads 20/20. His correction is plus 2 D. sph. minus .75 D. cyl. ax. 180.

Stenopaic Slit. A good test in many cases of astigmatism, especially myopic astigmatism, but not available in every case.

1. With the chart at 20 feet, under bright illumination, and the untested eye excluded, place the stenopaic slit before the eye.

2. Revolve the slit until the angle is found at which patient reads type best. If this be not 20/20, make it so by means of plus or minus sphere. This sphere is the measure and correction of one of the chief meridians of astigmatism.

3. Revolve the slit to the opposite angle, which will be that of worst vision, and repeat the process. The lens which gives 20/20 is the measure and correction of the other chief meridian.

4. Calculate the compound of two cross-cylinders represented by the above corrections.

Thus, suppose, that the slit gives best vision at 90 deg., requiring minus 2 D. to make it 20/20. At 180 it gives worst vision, requiring minus 3 D. to make it 20/20. The needed correction, then, is two cross-cylinders, a minus 2 D. ax. 90, and a minus 3 D. ax. 180. The compound equivalent is minus 2 D. sph. minus 1 D. cyl. ax. 90. The problem is worked out in

the same way, whatever the findings, always bearing in mind that if one meridian proves to be minus and the other plus, the difference between them is the sum of the two numbers.

Chromatic. With a small circular light at 20 feet distance and the cobalt lens before the patient's eye, proceed as follows:

Reading. The commonest method of testing at reading distance is with the Jaeger test types. Find the closest point at which the proper type for that range can be read; or place the chart at a certain distance, and then find the plus lens which will enable the patient to read the proper line of type.

Lockwood's Cross Cylinders. After finding as nearly as possible, by means of the foregoing test, the patient's reading distance, substitute for the type one of Lockwood's T charts, and place before the patient's eye a combination equal to a pair of 50 D. cross-cylinders, with their axes coinciding with the strokes of the T. If patient sees both strokes of the T equally black, the reading distance is correct; if not, add more plus lens power until they are seen equally black. The result will be the comfortable reading correction.

OBJECTIVE TESTS.

Static Retinoscopy. With a plus lens (objective) before the eye whose focal length represents the distance at which we wish to work, i. e. a 2 D. to work at 50 cm., proceed as follows:

1. If no shadow appears, the eye is emmetropic.

2. If a shadow is seen moving with the mirror, the eye is hyperopic. Find the plus lens which abolishes the shadow. This lens is the measure and correction of the error.

3. If a shadow is seen moving against the mirror, the eye is myopic. Find the minus lens which abolishes the shadow. This lens is the measure and correction of the myopia.

4. If, upon beginning to shadow, the edge of the shadow is seen to tilt away from the vertical, the eye is astigmatic, with one of its chief meridians coinciding with the edge of the shadow. The eye is then to be shadowed across this meridian, and in the opposite direction.

5. If, upon shadowing the horizontal meridian, as correction is approached, a band of light is seen to lie across the pupil in

that direction, the eye is astigmatic, and upon completion of the horizontal meridian, the vertical meridian must be shadowed in the same way. See 1, 2, and 3.

6. After shadowing each meridian separately in an astigmatic eye, the correction is calculated as from two cross-cylinders of the power indicated. (See Stenopaic Slit). Or,

7. Having completed the correction of one meridian, a cylinder of the given power may be placed before the eye, its axis at right angles to the meridian in question, and the other meridian may then be shadowed and corrected as a sphere.

Dynamic Retinoscopy. An excellent method of finding a patient's comfortable near point. With distance correction on, the accommodation is fixed upon the mirror of the retinoscope at a given near point—say 33 cm.—and the movement of the shadow noted. If neutral, come closer to the eye until it is "with," then draw back until it is neutral again. The closest point at which neutrality can still be obtained is the comfortable near point.

When, as sometimes happens, the shadow movement is "with" at all convenient distances, place extra plus power before the eye and proceed with the test, allowing for the extra power thus utilized in prescribing the glasses.

Ophthalmometry. When the head-rest has been properly adjusted, and the telescope focussed, so that the mires are seen distinctly upon the cornea, proceed as follows:

1. Turn the revolving cylinder until the two central mires "line up," i. e. until the lines running through them are continuous with each other. This represents one chief meridian.

2. By means of the thumb-screw, bring the edges of the two central mires together, or separate them if they overlap, until they are just in contact. This records on the dial the dioptric value of the meridian under measurement.

3. Revolve the cylinder to exactly at right angles with its first position, where the mires will "line up" again. This represents the other chief meridian.

4. Separate or bring together the edges of the central mires again until they just touch. This records on the dial the dioptric value of the other meridian.

5. The difference in values between these two meridians is the measure of the astigmatism. The angles of the two chief meridians is shown on the dial.

MUSCLE TESTS.

Maddox Rod. This test, which is used for infinity only, is as follows:

1. Place the Maddox rod before one eye, and a red glass before the other. (If the rod is red, no other glass is necessary).

2. Direct attention to a round small light at infinity.

3. If there is no imbalance, the patient sees a bar of light and a round light, one red and the other white, in about the same lateral plane.

4. If there is esophoria, the bar and the light are separated in the same direction as the eyes viewing them.

5. The prism which, base out, brings the two images into the same lateral plane, is the measure of the esophoria.

6. If there is exophoria, the images are separated in the opposite direction (crossed diplopia).

7. The prism which, base in, brings the images together, is the measure of the exophoria.

8. By turning the Maddox rod to vertical, the bar will be seen horizontally, and the vertical balance similarly tested.

Phorometer. This, also should be used at infinity.

1. Set the prisms base in and direct patient's attention to small light at infinity. He will see two images.

2. If the two images are on same level, there is no vertical imbalance.

3. If not on same level, there is vertical imbalance. Turn the prisms until they are on a level, and this will record on the index the amount of imbalance.

4. Turn prisms base up and base down, respectively. Images are now doubled vertically.

5. If the images are in same vertical plane, there is no lateral imbalance.

6. If not in same vertical plane, there is lateral imbalance. By turning the prisms until they are brought into line the index shows nature and extent of imbalance.

Dot and Line. This is a finer test and therefore more suited for near test.

1. Placing the dotted line horizontally before the patient, at reading distance, put a 6 dioptre prism, base up, before the right eye. This doubles the line and dot, so that he sees two lines underneath each other.

2. If the dots on the two lines (true and false) are immediately underneath each other, there is no lateral imbalance.

3. If the lower dot is shifted to the right of the upper, there is esophoria, to be measured by the prism, base out, which brings them into vertical line with each other.

4. If the lower dot is shifted to the left, there is exophoria to be measured by the prism, base in, which lines them up.

5. Turn the line to the vertical, and produce double vision with a pair of 6 dioptre prisms base in. Test the vertical balance in a similar manner.

Adduction. With the eyes fixing a point of light at infinity, gradually add prism power, base out, until the image doubles. The amount of prism power with which single vision is maintained represents the patient's power of adduction.

It is important that the prism power be added to one eye only at first, until several dioptres are reached, and thereafter in equal amounts to each eye, so that there will always be considerably more power before one eye than before the other.

Abduction. Pursue exactly the same course as in adduction, except that the prism power must be applied base in.

Tetranopsia. Diminution of the vision by one-fourth.

Tetraophthalmos. A monster with four eyes.

Thalmus. A large ganglion in the optic tract.

Thrombosis. The gradual filling up of the lumen of an artery by accumulation of fibrous deposits. When this occurs in the central retinal artery there is a slowly developing anemia and blindness of the retina.

Thyroid. A large gland situated behind the sternum and in front of the trachea. Its only importance to the ophthalmologist is that in certain diseases of the gland there is a bulging of the eyeballs from their sockets, and certain other ocular symptoms. See **Exophthalmic Goitre.**

Tiedemann's Nerve. A nerve that enters the eye along with the optic nerve.

Tinea Tarsi. Same as **Blepharitis.**

Tobacco Amaurosis. Reduction of vision due to poisoning of the retina by nicotine from smoking excessively. It is usually in both eyes equally, and characterized by central scotoma. Vision is better at night. Abstinence from tobacco usually effects a cure.

Tonic. This word is applied to a muscle contraction that persists steadily, without intermission, as distinguished from a clonic spasm, which makes and breaks rhythmically. An example of tonic muscle spasm is seen in the ciliary muscle in latent hyperopia.

Tonometer. An instrument for measuring the tension of the eyeball. It belongs to the ophthalmic surgeon.

Toric. Torus. A form of lens surface which combines a sphere with a cylinder.

Toric Lens. See **Lens.**

Toxic Amblyopia. Loss of vision due to poisoning of the retina through the blood-stream. See **Amblyopia.**

Trachoma. A highly contagious inflammation of the conjunctiva, characterized by sago-like granulations, which greatly thicken the eye-lids and irritate the cornea, often to the production of growths on the later (pannus). Its diagnosis and treatment belong to the ophthalmic surgeon, to whom the case should be hurried the instant the disease is suspected. Mean-

time, the patient should be isolated, so far as contact with other people is concerned, and every prophylactic and hygienic measure taken for his own and other people's safety.

Tract, Optic. See **Optic Tract.**

Transillumination. The shining of light through a translucent medium. The inspection of a part or organ by means of strong light transmitted through it.

Transit. Passing across. In optics the word denotes the movement of the light area in retinoscopy.

Translucency. The property of transmitting light, without being transparent. Frosted glass is translucent, as it transmits light, but we cannot see through it.

Translucent. Transmitting light, but not transparent.

Transparency. The property of transmitting light without changing its character, so that one can see through a transparent body.

Transposition. Changing the form of a compound lens without changing its optical value.

In changing compound spheres and cylinders, the following rules apply:

The algebraical sum of the sphere and cylinder will give the power of the new sphere.

The power of the cylinder remains the same, but its sign and axis are reversed.

In transposing cross cylinders to a compound sphere and cylinder the following rules apply:

Use the power of one cylinder for the sphere.

Use the algebraical difference between the two cylinders for the new cylinder, with its axis the same as the other cylinder.

In transposing the compound sphere and cylinder into cross cylinders observe the following rules:

Use the power of the sphere for one of the cross cylinders, with its axis at right angles to the cylinder in the compound.

Use the algebraical sum of sphere and cylinder for the new cylinder, with its axis the same as that in the compound.

Trial Case. A case containing the necessary lenses and instruments for making subjective tests of vision and refraction. A well equipped case should contain:

30 pairs convex spheres
30 pairs concave spheres
20 pairs convex cylinders
20 pairs concave cylinders
10 prisms
1 Plain red glass
1 Opaque disc
1 Stenopaic slit
1 Ground glass disc
1 Maddox Rod Disc
2 or 3 Smoked glasses of different shade
2 Trial frames, 3 and 2 cell respectively.

The use of the trial case and its contents is described under the various tests.

Trichiasis. Scratching of the cornea by the eyelashes. See **Entopion.**

Trichitis. Inflammation of the roots of the eye lashes.

Trichromatic. Having three colors.

Trifocal. In some cases it is desirable to furnish a presbyopic patient with three focussing points, in which case three different focal curves are ground upon the lens, or two wafers, of differing focal curves, cemented on to the original lens. Such lenses are said to be tri-focal.

Trigeminus. A name given to the fifth cranial nerve, because of its three branches. One branch is the ophthalmic, which furnishes sensation to the eyeball and lids.

Triplopia. Seeing three images of one object. Usually due to a combination of heterophoria or heterotropia and an irregular astigmatism, i. e. a combination of a monocular and a binocular diplopia.

Trochlearis. The superior oblique muscle of the eye, so called because it passes through a pulley.

Tropometer. An instrument for measuring the degree of torsion of the eyeball.

Tunic. A coat, or container, of the eyeball. The eye has three such tunics, namely, (1) the retina, the nervous tunic; (2) the chorioid, or vascular tunic, giving rise anteriorly to the ciliary body and the iris; and (3) the sclerotic, or fibrous tunic, into which is set the cornea anteriorly.

Tutamina Oculi. Literally, the things that keep the eye safe. Applied to the protecting appendages of the eyeball, namely, the eyelids, the lashes, the eyebrows, etc.

Tylosis. Thickening of the lids, due to ulceration.

Typhlology. The science of blindness.

Typhlosis. Blindness.

Ulcer. A superficial, suppurating lesion.

Ultra-Violet Rays. Those rays contained in a beam of light whose wave-lengths are shorter and whose wave-frequencies are higher than violet waves, and which are therefore invisible to the human eye. The term is often erroneously used to include those high-frequency electric radiations with whose existence and use even the layman is so familiar, such, for instance, as the X-rays. Strictly speaking, it applies only to those high-frequency waves which are contained in a beam of white light.

The ultra-violet rays do not have any particular working interest for the refractionist, except insofar as it may be desir-

able to prevent them from entering the eye. This phase of the subject will be found discussed under **Actinic Rays.**

Umbra. A shadow.

Umbo. Apex. The umbo of a lens is identical with its pole, i. e. the extreme point of its elevation or depression.

Undulation. A wave-motion.

Undulation Theory. The theory, propounded by Huygens, that light consists of waves in ether, as opposed to Newton's corpuscular theory. (See **Light**).

Uniaxial. Having but one axis.

Uniocular. Pertaining to one eye only.

Unit. In arithmetic, the least whole number, or 1. All other numbers are assemblages or dividends of 1. In physics and mathematics a unit is a known determinate quantity by the constant repetition or division of which any other quantity of the same kind is measured.

Unit of Refractive Index is the index of air, which is numerically known as 1.

Unit of Lens Dioptrism is the lens-power necessary to focus paraxial waves in a distance of 1 meter, known as 1 dioptre.

Unit of Curvature is the curvature developed by a sphere with a radius of 1 meter, known as 1 meter curve.

Unit of Prism Deviation is a linear deviation equal to one-one-hundredth of the distance at which the deviation is measured, e. g. 1 cm. of deviation in 1 meter distance, known as 1 prism dioptre.

Unit. Angstrom's. The unit of measurement of the wave-lengths of the spectrum, established by Angstrom. It is ten millionths of a millimeter. This unit is seldom used in optics, the wave-lengths of visible light being comparatively large, and usually expressed in microns. Physicists who deal with high-frequency radiations employ the Angstrom unit

Upright Vision. The projection of an image by the brain in an upright position, in spite of the fact that the retinal image is inverted. Many ingenious theories have been propounded to account for this phenomenon. The real explanation probably is that the projection of the stimulus by the brain reaches back to the place where the light enters the eye, i. e. the cornea; so that what the brain sees is not, strictly speaking, the retinal image, but the corneal image, modified by the refracting media and the retina.

Uvaeformis. The middle coat of the choroid.

Uvea. A name given to the entire tissue system pertaining to the second or vascular tunic of the eye, namely, the choroid, the iris, and the ciliary body, as a whole. It is also called the uveal tract.

Uveal. Pertaining to the uvea.

Uveitis. Infection and inflammation of the entire uvea (See above). As the uveal structures all belong to the same tunic, they are frequently all involved in similar diseases.

V. Abbreviation for vision.

Vaso-Motors. A name given to the system of muscles and nerves supplied to the walls of the arteries (especially the small arterioles) and capillaries of the body, whose stimulation causes these vessels to dilate or contract, as the case may be, thus permitting an increased flow of blood to the area, or driving the blood out of it. The vaso-motors have both a general systemic action and a local action.

GENERAL ACTION.

The general, systemic function of the vaso-motors is to maintain, throughout the arterial system, the minimum blood pressure which is essential to life and well-being. The reflex centre which controls the vaso-motor system is located in the medulla oblongata, and, like all the centres in the medulla, is

an automatic centre, which, however, is subjected to influence by the brain. In health, and under ordinary conditions, this centre keeps a constant flow of nerve energy to the vaso-motors, thus maintaining a uniform minimum tone in the muscles of the vessels, which, in turn, maintain a uniform minimum blood pressure. Occasional physiologic variations, up and down, are produced by powerful mental emotions—anger, surprise, fear, etc.—but are rapidly equalized.

LOCAL ACTION.

The local function of this important system is twofold:

1. It insures adequate secretions at such points in the body as demand them, by dilating the vessels at these points and sending an increased blood flow to the secretory glands. Wherever increased glandular activity is temporarily needed—as at the stomach and small bowel during digestion—there, by an automatic reflex, the vaso-motors dilate the blood-vessels, and flood the glands with stimulating blood.

2. It equalizes the blood pressure in various parts of the body which would otherwise be disturbed by local differentials. Thus, when the splanchnic vessels are dilated during digestion, the dilated vessels are filled with blood at the expense of the vessels of the skin and muscles. The pressure in the latter vessels would fall below the minimum if it were not for the automatic action of the vaso-motors, which contract the skin and muscle vessels, thus maintaining the blood pressure.

The nerves and muscles which dilate the vessels are known as vaso-dilators; those which constrict, as vaso-constrictors. There is some dispute among physiologists as to the actual existence of vaso-dilators, many holding that vaso-dilation is the result of inhibition of the vaso-constrictors.

Venae Vorticosae. Veins of the eyeball. See **Veins.**

Vergence. The turning of the eyeball.

Vernal Conjunctivitis. Commonly called Spring Catarrh of the Eyes. An infectious type of conjunctivitis which attacks

children's eyes particularly in the spring-time and early summer.

Vertex. Properly speaking, the vertex of a lens is the point where its surface cuts the principal axis, and it therefore has an anterior and a posterior vertex. In ordinary optical parlance, however, unless otherwise specified, the term is used in relation only to the posterior vertex, i. e. the point where the posterior refracting surface cuts the principal axis.

Vertex Refraction. The vertex refraction of a lens is that power which, at the posterior pole of the lens, i. e. the posterior vertex, will focus paraxial rays of light at the principal focus. There is but one form and position of lens in which the vertex refraction is equivalent to its true or nominal refracting value, viz., a plano-spherical lens with its curved surface posterior. In this case all the refracting is done by the posterior surface, so that the nominal and vertex refraction of the lens are identical. In any other form and position, the refraction is divided between the two surfaces; and while this does not alter the true or nominal power of the lens, or change its focal length, the values of the two refracting surfaces are separated by a distance depending upon the thickness of the lens (the distance between the two surfaces) and the refractive index of the lens-substance. The two points of separation (known as the principal points) lie within the lens; the effect, therefore, is to lengthen the distance between the anterior surface and the posterior principal focus and to shorten the distance between the vertex and the posterior principal focus, thus making the vertex refraction greater than the nominal.

Since the location of the two principal points is a joint function of the thickness of the lens, its refractive index, and the radii of curvature of its two surfaces, it is possible, by a proper adjustment of these quantities, to make the Vertex power and the nominal power equal; and this is supposed to be done in the higher power lenses of a trial case.

The same principle applies to lenses in series, the refractive value of the last posterior surface of the series being the vertex

refraction of the series. This is the principle of correction of refractive errors of the eye by means of lenses. When we place a lens before the eye, it and the eye become lenses in series; and it is not that a plus or minus lens increases or decreases the dioptric power of the eye, but that it shortens or lengthens the vertex focal distance, or, in other words, moves the focal plane nearer to or further from the vertex of the series (the posterior surface of the crystalline lens), that effects the correction we are seeking. (See **Lens**).

Vertical. The specific application of this term in physiologic optics is to the extrinsic muscles of the eyes and their action. The vertical muscles are the superior and inferior rectus muscles, whose action is to move the eyeball vertically upward and downward, respectively. Vertical imbalance is an imbalance of these muscles. Vertical strabismus, a squint in which the eye is pulled up or down by one or other of the vertical recti, and vertical diplopia is double vision where the false image stands vertically above or below the true image, due, of course, to dis-function of one of the vertical rectus muscles.

Vertigo, Ocular. Dizziness caused by defective vision.

Virtual Focus. An imaginary focus, arrived at by projecting the rays of a divergent wave backward to the point from which they appear to have originated. (See **Focus**).

Visibility. The quality of being perceptible to the vision by means of light communication. The visibility of an object depends upon its ability to absorb some of the light waves which strike it, and to reflect others. If it absorbed all, it would be merely an area of dark; if it reflected all, it would be simply an area of light. By proportioning the two, it becomes visible as an object.

Vision. The faculty of seeing.

Double vision. See **Diplopia.**

Monocular vision. Seeing with one eye only.

Binocular vision. Seeing with both eyes at once.

Visual. Pertaining to vision.

Visual angle. See **Angle.**

Visual axis. See **Axis.**

Visual field. See **Field.**

Visual purple. A photo-chemical substance in the rods of the retina, whose dissociation by the action of light sets up visual stimulation of the retina. (See **Physiology of Vision and Retina**).

Visual Acuteness. See **Acuity.**

Visual Judgments. This is the name given in physiology to certain judgments exercised by the brain on the data supplied it by the visual faculty; such judgments are not really a part of the faculty of vision, but are so intimately connected with it as to be generally regarded as belonging to it. They are as follows:

Judgment of distance. Arrived at by a comparison of the size of the object with its size at some known distance; by the degree of accommodation and convergence necessary to view it, when it is within infinity. Outside of infinity, judgments of distance are very difficult to make.

Judgment of size. By comparing the size of the image (visual angle) with that made by other objects of known size and distance.

Judgment of solidity or third dimension. See **Binocular Vision.**

Vitreous. Literally, like glass. The name given to the humor which fills the posterior part of the eye ball, back of the crystalline lens to the retina. So-called because it has resemblance to glass. In fetal life an artery, the hyaloid artery, a branch of the retinal, pierces the middle of the vitreous from retina to lens, but after birth the artery disappears, leaving only the canal in which it lay, the hyaloid canal. Occasionally the hyaloid artery persists in extra-uterine life. The vitreous forms one of the refracting media of the eye, its index of refraction being 1.33, about the same as the aqueous humor.

Von Graefe's Sign. The failure of the eyelid to follow the downward movement of the eyeball in goitre.

Wall-Eyed. An expression applied to a person whose eyes give the impression of being immobile and staring. There are several causes for such an appearance, the commonest of which are divergent strabismus and amblyopia.

Warm Colors. The colors lying towards the red end of the spectrum.

Wave Theory. The theory, put forward by Huygens, that light consists of a disturbance in luminous ether which propagates itself in the form a spherical waves. It is at present the accepted theory, on which the science of optics is based. See **Light.**

Weiss' Test Types. A series of types arranged in intervals of a tenth visual acuity, to facilitate the determination of equal intervals of visual acuity without altering the distance at which the test is made. Weiss, however, does not approve of the method of expressing visual acuity in decimal fractions.

Wernicke Pupillary Reaction. A test applied to the light reflex of the eyes in case of hemianopsia, in order to determine whether the lesion is in front of or behind the optic thalamus. If it lies in front, there is no pupillary response to light thrown on the blind part of the retina; if behind, the reflex is intact.

Williams' Lantern Test. A test for color blindness by means of colored lanterns. See **Color Blindness.**

Wink. The quick closing and opening of the eyelid. Ordinarily this act is performed unconsciously, every few seconds, for the purpose of spreading the lubricant secretions of the eye over the globe, and sweeping away particles of dust. It is a true automatic reflex, brought about by irritation of the fifth nerve fibres in the eyeball. (See **Reflex**). Occasionally the reflex is due to retinal irritation of the optic nerve, as in bright light.

Winker. A common name for the eyelash.

Wollaston Prism. The prism used in the make-up of the Javal ophthalmometer, consisting of two quartz prisms so cut that when in position the base of each is at the apex of the other and the optical axis of each is at right angles to that of the other and to the axis of vision. See **Ophthalmometer.**

Wool Test. A test for color blindness in which colored wools are used as objects. See **Color Blindness.**

Word Blindness. See **Mind Blindness.**

Worsted Test. Same as wool test.

Worth's Amblyscope. See **Amblyscope.**

Xanthelasma. A flat, sulphur-yellow tumor which occurs on the eyelid, usually at the inner canthus, projecting a little above the skin of the lid.

Xanthocyanopia. Inability to perceive red and green, the color perception being limited to yellow and blue.

Xanthopane. A condition in which all objects appear yellow.

Xanthopsia. Same as Xanthophane.

Xeroma. Abnormal dryness of the conjunctiva.

Xerophthalmia. Conjunctivitis with dryness and atrophy.

Xerosis. Abnormal dryness of the eyes.

X-Rays. Also called Roentgen rays, after their discoverer, Wilhelm Conrad Roentgen. They are invisible radiations transmitted through the ether in a manner similar to light, and consist of very short, irregular, non-harmonic, electro-magnetic pulsations, capable of passing through opaque substances

approximately in inverse proportion to the atomic mass of the material. They are produced by passing uni-directional electric current of from twenty to a hundred thousand volts tension through a specially constructed vacuum tube, within which cathode rays from the surface of a concave cathode are focussed upon, and bombard, a target of refractory material, such as tungsten, platinum, etc., from which focus the Roentgen rays radiate in all directions in accordance with the law of inverse squares. Roentgen named them X-rays, because of the lack of knowledge as to their exact nature.

Yellow Spot. The most sensitive spot in the retina. Anatomically, it lies a little to the temporal side of the centre of the retina, and is distinguished under the ophthalmoscope by being lighter in color than the surrounding retina, owing to lack of vessels and pigment. Physiologically, it is the centre of attentive vision, only those parts of the image which fall upon the yellow spot being observed with attention and detail. It contains no rods, but cones only, and no visual purple. Optically, the yellow spot—or, rather, the fovea centralis, the central point of the yellow spot—is situated at the end of the visual axis in the image-space. See **Retina.**

Young-Helmholz Theory. The theory of color perception which holds that it depends upon the stimulation of three retinal elements, whose stimulation corresponds, respectively, to sensations of red, blue and green. See **Color.**

Zeiss' Glands. The sebaceous glands situated at the free margins of the eyelids.

Zinn's Ligament. A circular ligament at the optic foramen, attached to the bones of the orbit, with a circular opening through which the optic nerve passes into the globe, and from which arise the rectus muscles of the eye.

Zone of Zinn. A circle of vessels around the optic nerve where it pierces the eyeball, which supply nutrition to the substance of the optic nerve itself.

Zonula. Literally, a little zone. The zonula of the eye is the thin membraneous ligament which holds the crystalline lens in place. It is also known as the suspensory ligament. It is, in fact, a part of the ciliary body, from which it takes its rise, dividing and passing over the edge of the lens, forming its anterior and posterior suspensory ligaments, which are attached to the capsule. The triangular space between the zonula and the lens is called the canal of Pettit.

Zonule of Zinn. Same as **Zonula.**

Zonulitis. Inflammation of the zonula.

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